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BLUEGRASS PASTURE ALMANAC*

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The long summer leaves of bluegrass have turned brown, making the sere meadows and pastures of winter. In a few places, however, where these long leaves have been grazed off, pastures are still rather green. Bluegrass is also surprisingly green under certain trees and on the north slopes of hills. Isolated plants and small clones beneath apple trees in the orchard are brilliant green and are used by rabbits in preference to the tangle of brown plants in adjacent sod in full sun. Shading produces plants with leaves proportionately high in protein and low in fiber, which seem to satisfy the cottontails. Shading also restricts rhizome development sufficiently so that plants do not become crowded and thus sod-bound and nitrogen-deficient. After tree leaves are shed in fall, plants that were shaded all summer stay green well into the winter. When blades of these plants do die, they wither into very thin and delicate tufts, low in fiber, that contrast with the tough persistent dead leaves of sun-grown plants.

Hogs on the hill pasture are working up moist areas into black patches of open soil. Where a bed of limestone outcrops above a bed of shale there are seeps which keep the ground soft and wet. Hogs have made the contact of these two formations clearly visible across the hill (fig. 1). Their trails across the orchard-grass

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pasture are also very apparent now. In a part of this pasture which was left unmowed, the orchard-grass plants became rank and have been avoided by the hogs, not only in their feeding but also as they walk about the pasture. Consequently the pasture there has deteriorated into a rough tussocked run (fig. 2).

During winter when the ground remains frozen for long periods, bluegrass leaves become thin, wiry and twisted, with tips curving inward, probably as a result of the difficulty of obtaining moisture from the frozen soil. January leaves are very short, only an inch or so long. In areas closely grazed since fall, stock are hard-put to it to find enough to eat. Horses are able to eat close enough, but hay is being fed cattle.

The grazing habits of stock are distinctive and play an important role in determining the appearance of a pasture throughout the year. An important fact is that cattle and horses prefer grass which has grown in soil fed by the nutrients contained in their urine. They instinctively conserve the nitrogen, potassium, phosphorous, and trace minerals that urine contains and benefit from the stimulation which these substances, as well as dissolved hormones and vitamins, give the soil microorganisms and the herbage itself. This they do by actually seeking out the deep green grass which grows where urine has fallen (figs. 7 and 11). Analyses made by the author of grass in these spots has shown that it contains twice as much vitamin A (carotene) as ordinary grass, and Neven (1941) reports that the protein content of such fertilized grass may be nearly doubled.

Horses graze small areas intensively, but cattle range widely. Urine is distributed as the animals graze so that characteristic patterns of urine-fertilized grass develop. The pattern produced by cattle seems to be a rather random distribution over the pasture as a whole. With horses, however, urinations occur in small areas where the grass is kept closely grazed (fig. 7). The urine characteristically falls either on this short grass or, when grazing pressure increases, along the edges of these grazings (fig. 12) in which case it has the effect of continually enlarging the intensively grazed area (fig. 13).

Of equal significance is the distribution of manure. Stock avoid grass around their own manure clumps as instinctively as they seek out that fertilized by their urine. Cattle manure is scattered rather indiscriminately though there is some considerable concentration in loafing and bedding areas. Horse droppings, however, are somewhat controlled and deliberately concentrated in certain spots around the pasture. Often these spots are low places or fence corners; almost invariably they are weedy, full of rank vegetation. By keeping the manure thus concentrated and out of the way, their system of intensive grazing on small urine-fertilized areas is not interfered with.

Since in summer, stock avoid grass around clumps of their own manure, "rough" areas of rank grass are protected from consumption (figs. 9 and 13). Considerable forage is thus saved for winter use. When the manure is frozen it no longer seems to be objectionable. In January, when new grass growth is at a

minimum, these areas are brought into use. Clumps of manure previously protected by grass are now exposed, and to some extent are being scattered about the pasture. These "roughs" provide a convenient emergency supply of fodder when freezing rains and sleets fall. Urine grazings become a solid sheet of ice, but roughs, drifted with a little sleet, are still rather soft underfoot, and horses can paw them with their hooves, scrape away the crust of snow, and obtain all the grass they need (fig. 3). Cattle are not quite so adaptable and must be fed. No matter how heavy summer grazing may be, reserves of long grass around manure will usually be saved for overwintering. If fall months are very dry, however, grass growth will be slow throughout the pasture and "rough" reserves will be invaded during October and November so that before winter is over roughs may almost disappear.

The past summer certain small blocks of pasture were enclosed with fence so that stock could not reach the grass within them (figs. 1 and 10). This protected grass has grown rank, and I can be almost certain that in each "exclosure" a rabbit will be spending the day. In fall and winter rabbits like the rich proteinaceous grass nourished by stock urine. By using these protected islands in the pasture they have access to much of that fertile grass, and their pellets are often found in closely grazed urine grass.

The rabbit's midwinter desire for proteinaceous food, which apparently accompanies the advent of the breeding season, is satisfied by grazing intensively small plots of grass which have been fed urine by dogs, stock, man, or by the rabbits themselves. These grazing places are eaten down into the dirt with nothing but bare soil remaining (fig. 4). Such rabbit pastures are common sights along the runways of rabbits in winter orchards. They can also be seen occasionally in the summertime (fig. 20).

In some places mice grazings are just as conspicuous. In October some urine was poured in a circle around a stake placed in an old Canada bluegrass meadow. Now the grass which received urine has been completely consumed and the ground is bare in a circle around the post (fig. 5). Even the rhizomes have been eaten. More striking still, where some of the urine had fallen on the post, the wood was chewed up by the mice.

Gophers are no longer busy bringing up their piles of dirt as they were during fall (fig. 6). The extensive bulldozing they did then is slumping down with the frost and being scattered by treading hooves and being undermined by rhizomes of bluegrass. Most fall gopher mounds are built after temperatures are low enough to keep weed seeds from germinating. Also in fall and winter rhizoming and tillering of bluegrass are very active, and the new loosened aerated soil in the mounds encourages the vigorous vegetative development of bluegrass plants around its edges. The invasion and conquest of the mound go on to some extent all winter, for the loose soil does not freeze deeply. Revegetation of these mounds is

also accomplished by plants which have been buried beneath the soil. When leaves and crowns are covered, internodes elongate and bring the crown up to the surface of the mound. Branching of rhizomes, while infrequent in most places, is the order of the day in gopher mounds.

February

Wherever the pasture thaws during the winter, stock cut the sod with their hooves and create large scars by sliding and slipping. These scars usually heal rapidly if made in early winter, but may remain for a considerable period if made in late spring. When the snow is soft, horses moving about build up pads of snow on their hooves. When these pads later slip off, many weed seeds and even vegetative parts are carried about and planted. From a single pad picked up in February, 28 plants were germinated. Sixteen species were represented, half of which were grasses (Etter, 1948).

During these cold months the rhizomes of bluegrass which began to grow in late October and November behave much as do the bulbs of such early spring plants as jonquils. Being situated near the surface of the soil, however, they are more subject to variations in the weather. They grow slowly in late fall, fitfully with thaws in the winter, and rapidly in the spring, shooting up and developing into new plants. At any time in winter one may find, in places where growth is rather vigorous and fall grazing was not too intensive, small rhizomes which are all white. Those which did considerable growing in fall have slightly green tips, and others may show a few short leaves.

The dominant process, of course, during winter in every bluegrass plant is tillering. In old meadows this proceeds at a snail's pace, but along streams, in loose, rich soil, where plants have room to stretch and root, it proceeds rapidly. More subtle is the secret development of the bluegrass seed head within enclosing sheaths. This process may have begun as early as November or may wait as late as March, depending on variety and environment.

Winter thaws are important to bluegrass. With only a little rise in the soil temperature above freezing, fat white roots develop from the new tillers which have originated during the previous months. These roots, in turn, appear to stimulate new buds to develop into additional tillers. Where the soil is protected by an overburden of long leaves, thawing is slower and less frequent and roots do not develop very rapidly. Well-grazed or isolated plants, however, begin to send out roots a few hours after the soil thaws. This may play an important part in the earliness and the more vigorous growth of open-grown or spaced plants often observed along paths, in alluvium, in gardens, or near buildings. It is certainly true that bluegrass is often early to flower on the south sides of buildings and hills, above subterranean steam pipes, under eaves that drip warm water frequently in winter, or in places that are protected from snowdrifts as on the south sides of evergreens.

In meadows, now, there are well-camouflaged tunnels through which mice circulate in contempt of the winter weather. These are not mere pathways to and from, but feed alleys along which mice find their food. The stems of grass are cut near the ground to make the tunnel. When new leaves grow from the crowns of these severed plants, they stick up along the pathway. This growth is tender, bleached, and proteinaceous and is nipped off by the mouse as he navigates his pasture. These tunnels occur in heavy meadow grass where the overburden of leaves keeps the soil from freezing deeply, so that a small amount of blade growth takes place throughout the winter. Small feeding pockets extend short distances from the tunnels and are frequently filled with the grass-green pellets of mice. Undoubtedly the urine is also there. The floor of the tunnels and pockets is littered with clipped stems and pellets and is penetrated by a maze of bluegrass roots. When the ground thaws, the pellets disintegrate and a rich bed of mold develops, fed by these excretory products. The reserves of the rhizomes and crowns which feed the grazed plants are depleted by winter-long grazing and lack of sun, and tend, in spring, to produce weak growth which is often unable to reach through the overburden to the light.

When plants such as chicory and plantain, which have bulky storage crowns, grow isolated in rank meadows they are apt to be consumed over winter by mice or gophers. Two plants, one of plantain, one of chicory, which I had marked last summer have been cut down and their roots consumed and transformed into a pile of pellets.

March

A little warm weather in late February and March is soon followed by a slight greening-up of pastures. Earthworms return to the topsoil and robins arrive in time to take advantage of them. Flocks of starlings and purple grackles are often found feeding on these early spring pastures.

During December and January bluegrass leaves tend to become short and prostrate, and leaves grow only about a half centimeter a week. When the days become longer and thaws are frequent, leaves and plants straighten up. New leaves shoot up from tillers and rhizomes which have developed during the winter. Since the snow, ice, wind, and treading cattle have broken the old tufts of grass in much of the pasture, these new leaves are not encased in the long sheaths of the previous year, and so become visible almost as soon as growth begins. Where leaves reach the light with a minimum expenditure of food reserves, they are inclined to be more vigorous, broader, deeper green, and more attractive to livestock than those which have had to struggle up to find light. During this greening-up period, little further tillering occurs, and this is one time of the year when virtually no rhizomes are initiated. Any rhizomes still underground turn up and proceed to develop leaves. Often after this green-up first begins, the weather becomes cold again and leaf blades become reddish at the tips and growth almost stops. This redness, apparently anthocyanin accumulation, is especially common in the

tips of grass recently grazed or cut. It seems to be a characteristic response of plants which are all ready to begin active growth and are prevented from doing so, either by injury, drought, low temperature, or excessively bright sun.

During this spring renaissance, reserves in the crown, roots, and rhizomes are used up to produce new leaf growth. Sods become remarkably weak and may be pulled apart more easily than at any other time.

Wherever urine has fallen on the soil since last September, bluegrass shows an early difference. Grass fed nitrogen does much more growing at low temperatures, below 40°, than does unfertilized grass (Blackman, 1936). At higher temperatures the nitrogen seems to have relatively less effect. Urine-fertilized grass is deeper green, thicker, and broader-leaved. Growth is also early in other sites where the ground is rich or moist, such as bare places once occupied by haystacks, near manure piles, in seeps, and around the edges of spots of sod burned out by urine last summer.

Now that the sod is becoming soft, hogs are taken off the permanent pastures. Where they have been fed is a litter of corn cobs and mud which will become a rank bed of rich weeds in a few months.

Horse grazings are now strikingly differentiated from the rest of the pasture which still is rather bleached (fig. 7). Tufts of grass fed by steer urine during fall and winter are now becoming visible, and cattle run in these early pastures seek out these patches. It is interesting that horse urine does not burn bluegrass when it falls on frozen ground. By mid-March, however, severe burning may occur. Cattle urine seldom burns grass even in mid-summer.

April

In early April dormant buds on the bluegrass crown begin to swell, anticipating the spring flush of rhizomes that accompanies flowering. At the same time, bluegrass florets and panicles are growing, getting ready for the grand elongation of the stem which will occur in a few weeks. Long green blades of bluegrass are waving in the wind. Where pastures were not grazed last fall the blades are long, three or four inches, while in grazed places they are only an inch or so long and form small rosettes. There are many more blades in the grazed area, however. In rich soil, closely grazed, there may be twenty or more blades to a square inch.

Trails and paths made through old meadows last summer and fall show up conspicuously now as stripes of green grass in a tangle of old whitish leaves. Breaking down the sheaths and shading growth gave short fall and winter leaves access to winter sun. This stimulated tillering. A rough count of leaves along such a pathway showed twice as many new spring leaves as in undisturbed parts of the field. This path was used only one day, when it was walked over only five or six times. It demonstrates very simply how fall discing or mowing and raking of neglected pastures will do much to improve them.

Down along the creek the succession of plants on newly built alluvial banks leads eventually, under grazing, to bluegrass. After gravel bars are stabilized by

sweet clover (*Melilotus officinalis* L. (Lam.), bouncing-Bet (*Saponaria officinalis* L.) and willow sprouts, coatings of alluvium begin to support a variety of weeds. Composites such as species of bur marigold (*Bidens* sp.), cocklebur (*Xanthium* sp.), sunflower (*Helianthus* sp.), as well as great ragweed (*Ambrosia trifida* L.), will also grow here, but will not withstand grazing and trampling. Rhizomes of *Muhlenbergia racemosa* (Michx.) B.S.P., broken loose from clones upstream, lodge on banks and begin to establish a rank stand of coarse grass which ties down the soil and speeds up deposition. As time goes on, bluegrass becomes established and invades and eliminates the other species. Without grazing, the succession would proceed from the coarse grass and weeds to shrub and tree growth. Grazed alluvial banks support excellent stands of bluegrass in the older established areas.

Other grasses are developing rapidly now. Orchard grass (*Dactylis glomerata* L.) is flowering, and quack grass (*Agropyron repens* (L.) Beauv.) and smooth brome (*Bromus inermis* Leyss.) are beginning to develop rhizomes, while Canada bluegrass (*Poa compressa* L.) sods, devoid of new leaves, show many long white rhizomes which have not yet turned up. Redtop (*Agrostis alba* L.) is still almost dormant, a few green leaves beginning to appear. Purpletop (*Triodia flava* L.) has made virtually no growth, although its white dead stems are prominent in parts of certain pastures (fig. 8). On south slopes dandelions are just appearing, and in thin places a variety of small seedlings now appear. Old chicory (*Cichorium Intybus* L.) plants show only a few small leaves.

Earthworms are abundant and are throwing up extensive castings within the secrecy of the grass. This subtle cultivation, accompanied by an increase in the numbers and activity of nitrogen-fixing bacteria in the soil, comes at the time when bluegrass needs it for rapid nitrogen-consuming leaf growth and inflorescence development. Moles are busy now too, tunneling in well-drained places, but gophers seem strangely absent. Cottontail rabbits are using wads of last summer's long grass to hide their nests in. Young cottontails will be venturing from these nests very soon.

By mid-April the blades on the flowering shoots of bluegrass have finished their development, but they are still telescoped within each other, waiting for the elongation of sheaths and internodes. The panicle or flowering head can be found just within the sheath of the newest leaf. It is striking to note that shoots of bluegrass which are going to bloom this spring can be easily selected now, because they have shorter and wider leaves than the blind or non-flowering shoots, and they are conspicuously a deeper bluer green.

The short winter leaves are beginning to turn yellow, and this dulls the greenness of the pasture very slightly. When stock graze the pastures now they are getting not only leaves but the developing flowers within. Mowing or close grazing at this time will greatly reduce the flowering of pastures. It will also produce a silage or feed as rich in protein as bluegrass can produce. It may, however, be a little short on sugar. By waiting a few weeks for the panicles to develop

a little further a heavier yield will be forthcoming and the carbohydrate content will increase, though the per cent protein will drop accordingly.

Old gopher mounds are now drying out and are very evident in pastures grazed continuously, for the grass there has not been given much chance to cover them (fig. 6). Bluegrass plants which grow on these mounds are very distinctive; the leaves are short and wide, deep blue-green, are prostrate, and often have much anthocyanin in their blades. Flowering shoots are consistently early to appear and grow almost horizontally.

Winter pigs are on pasture now and they thrive on the high protein of the new grass. They are also busy rooting for worms and other foods in the loose soil under walnut trees. In a few weeks they will be seeking clover. Where hogs were pastured during the cold months, what grass remains is now a brilliant green. Hog urine has an especially strong, though brief, effect on bluegrass, and that combined with the well-distributed manure and treading stimulates the grass as it is stimulated in few other places.

The excretory behaviour of swine is quite as interesting and significant as is that of cattle and horses. Hogs, when penned, are very careful to drop their manure only in certain corners. When on pasture they are careful to keep both urine and manure from contaminating the bedding area. Consequently, both waste products accumulate just outside the sleeping area, where sleepy hogs politely retire. Swine are just as careful not to defile their rooting areas, although here the prejudice is limited to the solid droppings. They do not hesitate to urinate in their excavations or in their wallows. Since hogs have need for various trace elements and antibiotics, it is quite possible that wallowing may be more than merely a way of keeping cool. The continual dabbling and rooting and munching that goes on while pigs search their wallows may provide them in a natural way with nitrogen, animal protein factors, and trace elements.

Almost invariably, after rooting and wallowing, hogs leave along some much-used path, travel a few hundred feet, drop dung just off the path, and proceed with the day's affairs. Where pastures are intensively grazed and where corn supplements, minerals, and water are provided all close together, these patterns are broken down and feeding areas are littered with manure. Frequent worming then becomes a necessity.

In a pasture grazed last fall for a few months by steers at a rate of about two head per acre, there now appear as many as 20 urine spots in a plot 45 feet square, or about 1 square foot of urine grass to 40 unfertilized. In a pasture grazed longer and more intensively the spots are so close that I can easily step from one to the other. An important result of the stimulation of these pastures by urine is that bulky and less nutritious plants which might ordinarily be avoided are consumed to provide the necessary bulk. It is a common observation that the more rich proteinaceous food an animal has the more bulk it can handle.

It is rather easy to tell approximately when the urine fell which stimulated a certain piece of sod, for the vegetative response to fertilization depends on the season when it is applied. Urine applied in fall promotes vigorous tillering which leads to short leaves and many short inflorescences with heavy loads of flowers and a decided blue-green color. Spring applications produce leaves as long as the inflorescences. These shoots are weak, short, bear few well-developed flowers, and often lodge. With such information it is possible by examining urine spots to tell approximately when and how long an area was grazed. It is interesting that pig and calf urines have no such effect as do hog, beef, human, or mare urines. The difference in the reaction of the grass may be due partly to the characteristically lower nitrogen content of urine from a growing animal, or to a different hormonal content.

The effect of urine on the grass of pastures is not limited to a single season, although the striking flush of growth in spring is the response most commonly seen. There is a more lasting influence as a consequence of the fact that urine stimulates the development of grasses more than it does of weeds, especially when applied in winter. This rapid growth smothers out weed seedlings, clover plants, and results in a pure stand of bluegrass. Urine holds down weed development in a second way. From controlled tests made in flats kept in a greenhouse and planted to a variety of pasture weed seeds and grasses, it was found that germination of weed seeds was strongly inhibited in flats treated with urine, while grass seeds suffered little if any such inhibition. This effect was just as marked when urine was applied to plots of bluegrass in the pasture or on a lawn (fig. 14).

In pastures grazed last summer by the horses there is much clover. Horse pastures characteristically contain more clover than those grazed by cattle. This is due in part to four facts: (1) Close grazing encourages clover, and horses graze quite close. (2) Compaction of the soil in certain areas maintains a favorable moisture condition for germination. (3) Breaking of the sod during winter induces germination of clover seeds, and horses cut the sod more than cattle. In a simple chopping test where a rank sod of pure bluegrass was cut with numerous strokes of a hand axe while the ground was frozen, clover germinated the following spring to such an extent that boundaries of the plot could easily be discerned. Winter discing also favors clover. (4) Most interesting relationship of all, however, is that involving urine and grass. Horse urine that falls on growing grass usually kills it; cow urine does not. Burned patches soon become bare ground. While weather and soil conditions influence the flora that develops on these spots it is especially characteristic that spots which develop in dry mid-summer or fall remain bare until the following spring. At that time clover seedlings take over the bare ground and by April the patches are solid in clover. The attraction which urine-saturated soil has for earthworms and many other burrowing organisms may lead to extensive aeration of these spots and so encourage clover germination also.

By the last week in April dandelions and peppergrass (*Lepidium virginicum* L.) are beginning to elongate, having already produced nutritious rosettes. Not only

has bluegrass begun active production of rhizomes, but the panicles of early-flowering bluegrass plants have already been exserted. Silica deposition in the soft culms is going on and stock are avoiding them now. Where grazing is close and intensive the tough stem interferes with the efficiency of the grazing procedure. The stem does not tear when the cow pulls on the leaves, but instead the entire plant comes up by the roots. Dead plants pulled up in this manner litter the turf in places.

At this season when growth is more rapid than at any other, a surplus of herbage soon develops and stock begin to pick and choose their preferences. A striking example of the attraction which urine-fed grass has for cattle now is shown in fig. 11.

May

During the first part of May flowering stems of bluegrass elongate rapidly, at least a centimeter a day. Ungrazed pastures become a sea of grass. Inflorescence elongation seems to have a depressing effect on the non-flowering tillers of the same plant, for many of them die during this period. They give the appearance of having been deprived of water. It is obvious that death of some plants and shoots must occur in a stand of bluegrass each year in order to maintain an even density over the years. In ungrazed meadow grass the greatest number of these deaths occurs at this time of year. There is also a gradual dying of the leaves on the inflorescence itself, all but the upper one or two having turned yellow at the tip.

Beneath the soil new rhizomes are more abundant than ever. Some will turn up in the next few weeks; others may turn up sporadically throughout summer. All will turn up by early fall. It is a striking fact that new roots virtually cease to develop after April, though elongation of existing roots continues.

Rank growth in the unknown meadows of last year, especially the prominent white stems of last summer's purpletop (fig. 8), begins to blacken with mold, weaken and collapse. Lespedeza seedlings are coming up in patches of last year's crabgrass, and both orchard grass and wild barley are showing their flowering heads.

Cows drop their manure indiscriminately on the grazing places of horses, ignoring the careful system which the horses would maintain. Horses will avoid the grass around these cow-manure spots for a short time but in general the taboo against using grass around manure applies only within the species. In Germany, it was often the practice to apportion horses and cattle to pasture in such a ratio that rough areas were kept eaten clean, the horses cleaning up cow-dung patches, the cows the horse-dung grass. Cows are even now using some of the grass around piles of horse manure. Where horses graze with sheep, roughs are more evident (fig. 13); both species prefer the short grass, the sheep avoiding the grass around horse droppings almost as religiously as the horses themselves. Sheep drop most of their manure in loafing areas. What manure is dropped on the pasture is so easily scattered about that it seems to have very little residual effect. Grass fertilized

with sheep urine, however, has the same attraction as that fertilized by other stock.

During the last part of April when bluegrass leaves are soft and green, aphids are active, sucking juices from them. Very soon, however, lady-bug larvae begin reducing the aphid population, searching every blade its entire length for their green prey. In two weeks more these larvae will fatten and develop into full-fledged lady-bugs.

Now, in the last part of May, white clover (*Trifolium repens* L.) is flowering, and the inflorescences of Canada bluegrass are leaving the protection of surrounding leaves. Cheat (*Bromus* sp.) is ripening, yarrow (*Achillia Millefolium* L.) has begun to bloom, ironweed (*Veronia* sp.) is 18 inches high, and the first blades of purpletop are beginning to show. Kentucky bluegrass has mostly flowered and seeds are ripening. Steers have shifted from bluegrass to rosettes of redtop and are grazing them intensively. Since redtop blooms later than bluegrass it is still in an early stage of development, growing rapidly, and consequently more palatable and proportionately higher in protein and lower in fiber than the more mature plants of bluegrass. This is a demonstration of the general tendency of stock to seek during each part of the summer those plants which are immature. After redtop begins to flower, the leaves of pigeon-grass, purpletop and paspalum will be sought, and new lespedeza will be consumed eagerly. By the time these late-developing species have matured, cool-weather species such as bluegrass will have begun to develop palatable new fall growth.

It is interesting to see young rabbits cutting the tender flowering shoots of bluegrass that grow on rich creek-bank soil, then eating them, flowers and all. Occasionally they will prefer a dandelion stalk, which is consumed, stem, puff, and all.

Dung beetles are actively digging their tunnels into the soil, then excavating fresh manure which they carry down into their burrows. The soil brought up is spread out over the top of the cow dung, serving to keep the dung from drying out, inoculating it with a variety of soil organisms, and hastening the course of disintegration and the incorporation of this organic matter into the soil. Dung beetles play a significant part in maintaining the fertility of a heavily used pasture for they keep the cycle of fertility operating efficiently with little waste of time or material. Where pastures are lightly grazed, or merely mowed occasionally, there is not enough manure to maintain a dung beetle population, and manure that falls often remains undisturbed and undecayed for years. Under those conditions little if any fertility is restored to the soil by way of animal waste products. It is also significant that stock on rank pastures, where there is little clover or rich green grass, produce manure which is bulky, hard, and low in nitrogen. This has little attraction for dung beetles hunting a rich medium for their eggs to develop in. Manure of stock on rich pasture is loose and moist, and decays readily.

Machines which have been developed to cultivate intact sod by spiking or plugging the soil are following the precedent of the dung beetles, especially those devices which bring up small cores of soil and distribute them over the surface of

the grass. Much of the benefit of this machine comes from the loose soil which it adds to the surface of the ground and mixes with the litter of grass stems, encouraging their decay. In a small way, it simulates the natural process of flooding, whereby thin additions of alluvium from flooding streams are made to pastures on low ground.

Plots of grass experimentally burned in February are now decidedly more yellow-green than adjacent grass not burned. Inflorescences are less green and less full. Since the ground was moist and frozen when the plot was burned and the fire not at all hot, there was little if any consumption of decayed nitrogen-rich litter from the soil surface. The only loss was the overburden of summer leaves. The evidence of nitrogen deficiency in the plants and flowering shoots of the burned plot suggests that the tangle of leaves makes an important contribution to the nutrient economy of an ungrazed meadow.

A bluegrass pasture that is maintained by light grazing or mowing reaches a stability that is the result of a complex interrelationship of many factors. If we look down at it closely, it is a veritable jungle with many kinds of insects walking in and out among the fallen stems. There are worm castings, mouse droppings, white molds, and minute fungi. A few attenuated weed seedlings try to reach the light. Bluegrass roots come up during the summer into this community and feed, and they are as dependent on a balance of these organisms as they are on rain. As a matter of fact, in this litter moisture is retained, and the molds and fungi, thus encouraged to develop, release nutrients and build up important organic compounds. Prolonged mowing experiments which remove leaves to be dried and weighed for assays discourage this natural process and inevitably interfere with production. Many such tests, repeated year after year, report unexplainable declining yields as years go by. There is little doubt that destruction of the reigning balance of nutrient release inhibits forage production. Summer roots have no place to feed.

Disruption of the balance in a meadow sod by burning or continuous removal of clippings with consequent weakening of the cover encourages perennial summer grasses such as purpletop or broom-sedge which demand less nitrogen. With repeated burning it has been shown (Curtis & Partch, 1948) that fire can weaken bluegrass enough to allow prairie grasses and forbs to become established. This weakening involves, in all probability, the discouragement of tillering.

June

In early June bluegrass inflorescences are still mostly rather greenish-yellow, though some patches tend to be more purple, or red. There is also much difference in the heights and leafiness of the flowering shoots. At first glance one might believe that the different patches are clones, displaying inherent differences but such is not always the case. Bluegrass is a very flexible plant, and it is subject to an unbelievable variety of influences and environments. Urine spots alone cause the development of many false clones, either by stimulating certain patches, or by

encouraging grazing in certain places. The differences between fertilized grass or grazed grass, and adjacent grass which has not been treated is often so striking as to seem uninterpretable except on a genetic basis. Time and degree of fertilizing influence the length and number of inflorescences and leaves. Close fall and winter grazing will produce plants with numerous small inflorescences and short leaves. Lack of fall grazing results in fewer and much longer flowering stems and longer leaves. Spots entirely avoided by stock for one reason or another will contrast with those which are grazed.

Treading also has its effect. Where pigs pastured intensively in winter, bluegrass is hardly flowering; the few inflorescences present are much shortened. The combined influence of actual killing of crowns by hooves, and the weakening effect of continual injury and nitrogenous fertilization played a part in preventing blooming. It was found, however, that hoeing of all top growth of grass from the frozen surface of the soil during February did not prevent crowns beneath the surface from sending up flowering shoots in spring, but it did greatly shorten the inflorescence, and weakened recovery growth. This weakness persisted throughout the summer, and the area was invaded by many plants, such as horseweed (*Erigeron canadensis* L.), milk purslane (*Euphorbia maculata* L.), *Paspalum pubescens* Muhl., boneset (*Eupatorium* sp.), purpletop, and white clover. Panicles on this plot ripened several weeks early, were abnormally white, and are already dropping seeds.

During this flowering season inflorescences are often found which have barely appeared out of retaining leaves and then died. The heads are a gray-white color, and the condition is often called silver-top. It is caused, in many cases, by the larvae of a thrip which consumes the soft tissue of the developing stem at one of the upper joints. This severs the panicle from its source of water and food and prevents its further development. While this thrip sometimes causes trouble for seed-raisers, the severance of the seed-head at this early stage undoubtedly conserves much vigor for the vegetative parts. Where silver top is common, the grass is commonly deeper green, but whether this is cause or effect is difficult to say.

Chicory is beginning to flower now. In Missouri this plant is an abundant weed along highways and in pastures. It does not become especially noticeable until June, spending both spring and fall as a prostrate rosette. Stock like to graze it in its immature stages, and to some extent even after its milky fruiting stems have begun to elongate. The seed of the plant is used as an ingredient of some pasture seed mixtures in England and has even occasionally been tried in this country. It has a long large tap-root which penetrates the soil deeply and thus serves some of the functions of sweet clover and alfalfa. Where pastures are not grazed in spring, chicory plants develop into tall bushy weeds full of pale blue flowers. Although adding a touch of beauty to a pasture, they become tough and inedible and leave their resistant stems to clutter up fall and winter grass.

In many cases where chicory has become objectionable, it is because the affected pasture was consistently not grazed in spring. If stock are allowed access to it at that time they will graze it closely and reduce its vigor. Fields along streams are

especially subject to chicory infestation for the simple reason that floods frequently break through fences during the spring season. Procrastination in repairing these fences often gives the chicory time to develop and seed, and build up reserves. Then when pastures elsewhere are grazed out, the fences are repaired and stock turned in on the low fields full of mature chicory. This gets rid of the overburden of summer grass, so that in fall when the chicory plant again assumes a rosette type of growth and begins to store up food supplies, it has full access to sun.

A single year's experiment to determine the effectiveness of spring grazing on restricting chicory growth was tried in some paddocks which had been ungrazed for some time and contained a heavy stand of chicory. Stock were allowed access to one paddock during April but were kept off the others till June. By July a strong reduction in height and vigor of the chicory stand was noted on the grazed paddock (fig. 18). The prominence of many weeds in certain fields can thus be traced back to the interrelationships of farm management and seasonal events.

By mid-June the tedious mowing of permanent pastures has begun (fig. 15). Although it is customary to wait until the seed head reaches its full growth before any mowing begins, it is quite probable that earlier clipping might be advisable so that the resources expended on production of the inedible mature panicle might be conserved for vegetative development. The observations already made of tillers dying during the period of elongation indicate that the plant is under stress at this time.

Earlier clipping would also prevent swaths from being so heavy. The bluegrass plant in the early flowering stage, when the panicle is just barely visible, is still fairly nitrogen-rich and soft and decays rapidly. As weeks pass, however, stems grow tough and siliceous, lie heavy on the new growth and disintegrate slowly. Even though the swaths are apparently obliterated in a couple of weeks by the rapidly growing June leaves, these leaves are forced to grow unnecessarily long through the weak light of the overburden and so deplete their food reserves. While it is essential to return this organic matter to the soil, it would be better to send it through the more efficient system, the animal, instead of trusting to the slow and expensive plan of decay. This is where the importance of grass silage comes in. Cut when grass is rich and generally in excess, and at the period when it is most beneficial to the plant, it is converted into manure and urine, rather than allowed to sink down slowly in an expensive disintegration. In well-grazed pastures there are now three main types of vegetation:

(1) There are those areas in present use for grazing which are short, rich, green and non-flowering. These places indicate where urine fell this winter and spring. They are full of clover, buckhorn plaintain (*Plantago lanceolata* L.), and chicory, all of which are being readily eaten. The rich nitrogenous grass is eaten closely.

(2) There are also those areas that were grazed last fall and winter, but are neglected for the time being. These show up now with short but well-developed inflorescences of bluegrass, mingled with chicory which has developed short flower-

ing shoots. Chickweed (*Stellaria media* (L.) Cyrillo) is common here, testifying to the fact that close fall grazing weakened the stand and exposed enough soil so that seed could germinate and the young seedlings receive sunlight all winter. Being winter annuals, they thrive best when winter competition is eliminated. *Paspalum pubescens* is also common in these places, since by the time fall and winter grazing occurs, this warm-weather species has already built up its reserves. Since fall-grazed bluegrass is slowed down in spring and its leaves shortened, the shoots of paspalum get off to a good start in May. Foxtail grass (*Setaria lutescens* (Weigel) Hubb.) is also beginning to become prominent in this short bluegrass.

(3) A third kind of area distinguishable on the pasture is the rough about manure, where tall chicory and rank bluegrass grow, and little if any grazing is taking place.

While these three conditions can be separately described as general tendencies where the pasture has been continuously grazed, they necessarily grade into each other to some extent.

Heavy rains after a dry spell freshen up the bluegrass rapidly. Much of this rapid greening-up results from rhizomes which, caught underground during the dry period, were unable to move. With the rains and resumption of rapid growth many of them come to the surface. Most striking response is that of the grass along shallow drainages in the pastures. Much of the reaction in this case is due not only to the availability of moisture, but to the concentration of the nutrients washed down or leached from the pasture hills above. In response to the accumulation of soil and nutrients in these shallow drains, they commonly support a vegetation distinct from that on adjacent slopes where removal of nutrient substances prevails. In one pasture, while the yellow soil of the slopes was thinly covered with a pure stand of Canada bluegrass the dark-soiled draws were distinctly marked off by tongues of Kentucky bluegrass. In another pasture, very poor and overgrazed, the hills were sparsely covered with triple-awn (*Aristida oligantha* Michx.), and lespedeza, with clumps of goldenrod (*Solidago altissima* L.) protecting a few remaining patches of old top-soil. In the gullies were chains of undernourished cocklebur.

Canada bluegrass is flowering now, and timothy heads are abundant in a few pastures and in the orchard. Redtop panicles are just now appearing. Ironweed flower buds are forming, lespedeza is coming up in pastures rooted by hogs this spring, and squirrel-tail grass (*Hordeum jubatum* L.) whitens the marshy swales in the hog pasture (fig. 16). This plant has the reputation of causing considerable difficulty with stock, especially when its heads find their way into hay. The bristles on the grain cause mouth injuries and open the way for more serious infection through diseases. Occasionally now small grasshoppers appear in the grass, and the first horseflies are giving the saddle-horses trouble. In a few parts of a Canada bluegrass pasture which I fenced off, rabbits have grazed the grass very closely. In these spots, opened up to the full strength of the sun, seedlings of buttonweed (*Diodia teres* Walt.) and also of sheep sorrel (*Rumex Acetosella* L.) come up, giving the appearance of small clones.

In a 15-acre pasture where a single horse had been grazing for 12 days I counted 18 newly burned urine spots on a plot 50 feet square. Since a horse averages around 7 urinations a day, in 12 days there would have been 84. If these urinations had been distributed evenly over the pasture there would have been only a third of a spot on 2500 square feet of the counted area. The concentration was actually 54 times that, indicating the extent to which grazing and urination are localized. The site of these counts was near the exclosure on the terrace in fig. 1. The soil was a rich fill and benefitted from subirrigation from the slope above.

Cattle, after having been turned into a pasture where pigs had run all winter, found many of the rank weeds to their liking. They ate avidly of the lamb's-quarters (*Chenopodium album* L.), tall smartweed (*Polygonum lapathifolium* L.), giant ragweed, and chicory (fig. 17). In a few days they had almost cleaned out even the Mexican tea (*Chenopodium ambrosioides* L.) and cockleburs (*Xanthium* sp.). They seemed to thrive on these weeds, even though the cockleburs are sometimes considered quite poisonous in their early stages of growth. About the only plants that the cattle could not stomach were common smartweed (*Polygonum Hydropiper* L.) and lady's-thumb (*Polygonum persicaria* L.). Consequently these two plants are taking over the old hog-feeding area. This indulgence in weeds took place at a time when plenty of good pasture was available.

July

The grass of pastures which have gone ungrazed is rank and lax, and is disregarded or trampled underfoot by stock. Where bluegrass has been kept short by continuous grazing, weedy annual grasses such as foxtail and crabgrass (*Digitaria sanguinalis* (L.) Scop.) come in. The former is especially common in closely grazed urine places, and actually contributes considerable forage. It is beginning to bloom, however, and that reduces its palatability. In the pastures not so closely grazed, stock are feeding on summer perennials such as purpletop and *Paspalum pubescens*, new shoots of sweet clover (*Melilotus* sp.), prickly lettuce (*Lactuca* sp.) and new lespedeza.

Pastures on low ground, partly as a result of extensive rains in June and July, are becoming much more rank and weedy than during previous drier summers. Bur marigold (*Bidens* sp.), *Croton capitatus* Michx., wild carrot (*Daucus Carota* L.), chicory, and *Paspalum pubescens* are coming up everywhere. When these weeds are cut during July mowing they leave a heavy swath which smothers out the grass and provides open areas where new weeds such as corn gromwell (*Lithospermum arvense* L.) can come in. At the same time, in an exclosure on this moist and rich low ground where no mowing at all went on last summer, much grass has drowned itself out, and weeds such as bull nettle (*Solanum carolinense* L.), black nightshade (*Solanum nigrum* L.), sedges (*Carex* and *Cyperus* sp.), and pokeweed (*Phytolacca americana* L.) are invading. The new poke plants are limited strictly to the vicinity of the fence, emphasizing that the chief means of

dispersal of poke seeds is by way of the alimentary tract of birds that eat the berries. Wherever convenient resting places such as fence rails, brush piles or fallen trees occur, there poke soon appears.

As these rank weeds develop in the grass, they shade it out. They are soon followed by giant ragweed and other rank bottomland vegetation, and eventually by elms and walnuts. On such rich wet ground removal of some of the rankness of the bluegrass is absolutely necessary for its own perpetuation. This can be most profitably accomplished by grazing, though careful late summer burning occasionally can be used. Mowing and raking is an expensive alternative. Upland bluegrass is much more stable and less subject to this self-destruction.

Although mowing in July is often done, it has little effect on pastures then except to shorten the grass for a time and postpone a little the flowering of certain prominent weeds. This postponement of flowering might help to reduce seed output were it followed later on with a second mowing. It often happens, however, that such mowings are never accomplished. Actually, many of these weeds are rhizomatous species, and occasional mowing seems to help more than hinder their spread. St. John's-wort (*Hypericum perforatum* L.) and chicory cut a few weeks ago already show flowers again. Ironweed (*Vernonia* sp.) comes back strong, and broad-leaved dock (*Rumex obtusifolius* L.) is scarcely affected.

When Canada bluegrass growing on exposed hills with little top soil is mowed, the hot summer sun has free access to the soil surface, which becomes dry and powdery. The slow process of restoring organic matter to these sterile places is consequently made even slower by indiscriminate mowing. Many farm practices such as manure spreading, fertilizing and liming, mowing and seeding, are done without reference to the natural conditions of the land. No effort is made to use ecological information to reduce the expense of wasteful blanket measures. Seed is not suited to the site, and treatment is not suited to the plant. The manure spreader is put into gear and manure flies over raw points and rich fills alike. As much seed is used on rich as on poor land. Alfalfa may be sown not only on suitable slopes, but on the poorly drained swales between. Mowing is performed when and where the opportunity offers without reference to the developmental stages of the plants or the nature of the soil. Heavy swaths smother bottomlands, and on thin soils the shrivelling litter offers no protection from sun and rain. To achieve maximum production and balance on an uneven farm, the ecological factors must enter into the picture.

Now that the spring drouth has been broken, rhizomes of bluegrass are elongating again. The drouth period is recorded on the rhizomes in the form of several extremely short joints, or internodes which contrast with the new ones nearly an inch long. While the axillary buds on these rhizomes seldom develop under ordinary sod conditions, this new flush of growth has resulted in considerable branching from the first one or two nodes of new growth. This branching seems to be a characteristic response of many plants to a break in drouth.

Gophers are throwing up mounds again. The fresh excavations are often disturbed and scattered by the mower bar during clipping of the pasture. They are also scattered by quail that use them for dusting places (fig. 21). These summer mounds usually develop a flora quite different from that of mounds pushed up in late fall. They are most commonly invaded by fleabane (*Erigeron annuus* (L.) Pers.), though also common are ironweed, boneset (*Eupatorium* sp.), thistle (*Cirsium lanceolatum* (L.) Hill), and other plants which germinate in summer, live for a fall and winter, and then flower the following summer. Old gopher diggings are often identified from a distance in summer pasture by patches of fleabane such as that shown in fig. 19.

Bare soil areas are also prominent where horses stand head to tail, brushing constantly at the horse-flies that are now abundant. The continual stamping of their feet digs up the soil over a considerable area. On windy days horses usually retreat to some exposed point high on a hill where their efforts are assisted by the wind.

In low shady places where the steer manure of last winter has remained moist, seed of honey-locust which passed through cattle undamaged have germinated, demonstrating one of the ways by which this plant spreads over pastures and waste land. Seeds of other plants also are able to navigate the alimentary canal of stock. From a small amount of hog manure planted in a flat with sterilized soil, bluegrass, nimble-Will (*Muhlenbergia Schreberi* Gmel.), goosegrass (*Eleusine indica* (L.) Gaertn.) and Mexican tea germinated (Etter, 1948).

August

Although August, like July, is usually a hot month, its days are noticably shorter, and it is perhaps this difference that makes bluegrass change for the better toward the end of the month. Often following a good soaking rain leaves seem to become a deeper color and broaden out slightly. Stock will leave their summer diet of purpletop, foxtail, lespedeza and weeds to graze the bluegrass where it has been kept short by summer traffic or close mowing, or where it has been grazed over by chickens for some time. A little anthocyanin may appear on the upper surface of leaves and on rhizome tips beginning to turn up. Some of the dormant summer buds on the crown of the plant have swollen. Most significant is the resumption of root initiation. As the month nears its end, short sprout-like rhizomes often develop, especially on meadow plants which have flowered. A rare plant or two, growing in a rich aerated nitrogenous soil, may even show the first development of a new tiller.

This new activity depends on the availability of moisture, and if August is very dry resumption of growth may be delayed, to occur in a flush of activity after the first rain. While no amount of water in July can make bluegrass really palatable or healthy, irrigation in August and September is a different matter. By allowing fall growth to get away to an early start while days are still warm enough to encourage growth, total forage can be much encouraged and its nutritional

quality will be reasonably satisfactory. Where bluegrass pastures are depended on to provide overwintering forage in the fields, dry falls can be very serious.

Other early signs that day length is getting short enough to produce results are the first fall flowering of dandelions and of annual bluegrass (*Poa annua* L.) and of the development from dry Canada bluegrass stems of new fall leaves which attract rabbits. The fall crop of grasshoppers also finds that this grass is beginning to have what they need to bring them to maturity, but many of them still prefer other more succulent sources of food. In lespedeza fields which were being saved for seed quite a few weeds were developing, especially prickly lettuce (*Lactuca scariola* L. and *L. saligna* L.). Grasshoppers invaded the field and while completely ignoring the lespedeza, they consumed leaves, seeds and stems of the weedy species, and almost entirely eliminated the weed problem before combining began. Grasshoppers are so uniformly castigated that it is interesting to observe also that they sometimes attack the giant ragweed with particular fury, consuming leaves and flowering heads before much pollen has had a chance to spill. Grasshoppers are often just as choosy as cattle or horses about which plants they eat. In a field of ironweed, a very troublesome plant, grasshoppers may strip certain plants completely, leaving only the bare stems. At the same time adjacent plants may be untouched. Ironweed is a highly variable species, and there are considerable differences in the leaf as to its hairiness, thickness, toughness, and greenness. There are probably equivalent differences in the chemistry of the tissues. It is small wonder that when they can afford it, the grasshoppers are particular.

August is a time of spider webs, and in the morning dew-wet webs may be seen scattered widely over the pastures. They are also abundant in the woodland, and can sometimes be seen flying overhead on the wind.

Mowing in mid or late August, while not a common practice, is very beneficial to pastures where summer grass has grown abundantly and deep. Mowing should be done just late enough to catch the last flowering shoots of the summer grasses such as purpletop, broom-sedge (*Andropogon virginicus* L.) crabgrass and foxtail so that no regrowth will occur. The removal of this overburden will permit the short fall blades of bluegrass to reap the benefit of all the fall sunlight which plays a big part in the amount of tillering that occurs as well as the width of leaves and the nutritiousness of the grass. This mowing should be done early enough, on the other hand, to allow considerable fall top growth to occur. In Missouri, the third week in August seems a good time. Later mowing will reduce the crop of grass which may be used for fall grazing or saved for winter subsistence.

September

The change which bluegrass began to feel in August has now brightened up the pastures except in ungrazed places where long summer leaves have begun to die and turn brown. Growth is rapid, summer rhizomes are turning up and leafing out, and in good soil a few plants may begin to form tillers. Just as in March, this September rebirth of activity results in a temporary absence of rhizomes.

Except for a few short sprouts in the meadow or on wounded plants, they are almost impossible to find. In good soil which has had plenty of air, water, and sun during August vigorous plants develop, and these often begin producing rhizomes in September and continue all fall.

This fall growth is at the expense of stored reserves, and the growth it produces is rather proteinaceous, though low in sugars. Summer rhizomes in the soil are depleted and weakened. Sods tend to fall apart rather easily as new roots develop. New leaves are definitely shorter and broader and stock show renewed interest in bluegrass. They may lose weight, or gain very little during this period as a result of the low sugar-high protein composition of the forage, and at the same time dairy cattle often show signs of acetonemia, or sugar shortage. As the days get shorter and the nights cooler, however, sugars will begin to accumulate and by November bluegrass will have a fairy high carbohydrate content provided the pasture has not been excessively grazed in fall. While work horses take readily to this new fall grass after being turned loose, they seem generally to prefer to consume considerable quantities of the more mature higher carbohydrate growth of nimble-Will and crabgrass before settling down to bluegrass and clover.

Winter annuals such as wild brome or cheat are now developing, just in time to replace the summer grasses such as purpletop, now flowering, and crabgrass and setaria, which are becoming rank or dying out. Cheat is now four to five inches high and furnishes good pasture. It is much sought after by stock and will continue to provide pasture until well into winter. It will also return early in spring to give stock an early bite. This is the wild counterpart of such crops as winter rye or wheat, often planted for late fall and spring grazing. As a matter of fact, while man has laboriously devised through trial and error pasture systems involving winter annuals and hot-weather annuals such as lespedeza or Sudan grass to supplement permanent grass, nature does it automatically on pastures, and stock take advantage of it instinctively.

On a hill which was seeded several years ago to lespedeza and timothy there is now a striking demonstration of the advantage of mowing at the correct time (fig. 22). Part of this field was mowed the latter part of June, while the timothy heads were still green and the stalks tender. The lespedeza seedlings were just getting a good start. The other part of the field was not mowed until more than a month later. The heavy strawy swaths can still be seen on this pasture. The lespedeza seedlings, shaded during their early development and then covered with grass, have scarcely produced any fall forage. Lespedeza in bluegrass also benefits by early mowing in late May or early June.

October

If the fall has been moist enough, October pastures may be as green as those of spring, but drouth in September and October, a frequent occurrence, cuts seriously into fall grass production. The greenest grass, as usual, is to be found in disturbed areas, where vehicles have passed, animals or men have walked, or chickens

scratched, in gardens or where new soil has been deposited either by flooding creeks or eroding rains. In these places fall bluegrass plants produce many rhizomes and tiller early and are sought by stock. If the plants have been extensively injured during late summer, however, as by burning, or by the cleats of farm machinery or by hooves of swine, the recovery growth may be very deep green and actively tillering, but very few if any rhizomes will develop. In general, such rhizomatous pasture or meadow species as quack grass, smooth brome, or redtop follow patterns of development similar to bluegrass, though slight differences in time of maturity are reflected in vegetative responses. None of these species is actively developing rhizomes now.

Hogs are feeding on bluegrass again, as they did during spring, testifying to the return of high protein forage. Cool weather and short days cause bluegrass to produce short leaves and prostrate plants. Stock graze closely seeking the nutritious foliage. They are invading grass protected during summer by rank foxtail or purpletop (fig. 23). Areas where urine fell last spring are still preferred, though little holdover effect is apparent. In pastures grazed during September spots of green grass are beginning to show where cattle urinated, but it is apparent that urine spilled in the hot weather of July and August produces virtually no results. The combined heat and dryness of summer permit the nitrogen to escape. Plots on which urine was applied artificially in August and September gave an amazing demonstration of the difference a month made (fig. 24). This fact has important meaning for grazers, for while it is commonly felt that animals return to the soil most of what they take from it, the truth is that much of the value of urine is lost when it goes on summer pastures. This might well influence the type of management which the farmer chooses to practice during that period, especially the dairy farmers who return the waste products of their cows to the fields during summer. It is quite possible that summer applications of manure lose so much nitrogen as to be unprofitable. Storage under protected conditions until cold weather might be more efficient.

Where pastures were not mowed in late summer the grass is very slow to develop and few if any tillers and rhizomes have formed. Fresh horse urine still kills the grass, but invasion of these burned spots is rapid now, at least in moist soil where adjacent plants have begun active rhizoming. Stock are avoiding the tall green grass around manure clumps.

The cessation of root initiation during summer causes an accumulation of buds without roots. During fall this backlog is reduced, and by October roots develop as soon as buds mature. These fall roots are fat and white and contrast with the slender wiry roots of summer.

There is now much mole activity, and gophers begin to build mounds out into closely grazed places seeking the succulent plants of dandelion and chicory. Clover is blooming a little, and aphids are back on the soft grass leaves. Under the oak trees where horses stand, fallen acorns are cracked beneath their hooves, and the soil becomes dry and powdery. Quail come to these trees, enjoy dust baths, and

pick up fragments from the cracked acorn shells. In the woods pasture they follow the hogs that crack hickory and walnuts and acorns with their teeth. Fragments dropped to the ground provide the quail with a convenient meal.

Bluegrass is often noticably superior under walnut trees. While this may be a complicated relationship involving microorganisms and obscure biochemistry, it also involves in part the fact that walnut leaves are shed early in fall, sometimes by mid-September, when bluegrass begins its important fall growing. Other trees often retain their leaves until November when all warm weather has passed. The shade cast in summer by walnuts is not dense enough to weaken growth, but is sufficient to limit rhizome development so that the grass does not become sod-bound. The sun of fall then allows tillering to progress and winter reserves to build up.

To test the influence of shade on bluegrass between September and November, a shade of muslin sack was placed a foot above the sod at the same time that walnut leaves were shed. This shade was left on until late-shedding trees such as maples had become bare. It had a noticeable effect on grass leaves, making them more lax, waxy yellowish green, and delayed the death or browning of summer leaves. In addition it was later noticed that the body of the fall leaves was much different. The shaded ones were fragile and shriveled and gray, while those in full sun retained their shape well and died to a tough yellow brown. The repercussions of this treatment were not followed the next year, but undoubtedly influenced the quality of recovery growth in spring, as well as the size and shape of the florescence.

November

In November bluegrass begins to suffer from the short days and the cold. Following the first frosts and the first freezes the blades shorten and cling to the ground. Rhizomes in vigorous grasses continue to be initiated, and to turn up, as they will, more slowly through the early winter. Nearly every new bud that develops now becomes a tiller. Gopher mounds are being invaded by rhizomes from adjacent plants. When the fall has been dry, stock begin to graze the rough areas where long grass remains. Clover leaves have been killed by the frost and swine are feeding on bluegrass, young chicory, and acorns. Canada bluegrass is just beginning to send out its rhizomes, which will continue growing off and on all winter and will turn up next spring to produce flowering shoots.

Pastures where sows and pigs were running during August were so softened by heavy rains that the unringed sows were able to attack the sod and uproot much of it in their search for worms, roots and other food. These rough bare areas still remain, testimony to the results of delaying too long ringing of the sows (fig. 25). In spring these rootings will be a maze of weeds.

December

Occasional frost has little effect on bluegrass, but in December when the soil freezes, bluegrass growth slows down greatly. With several inches of the top-soil frozen the leaves often turn dark, become flushed with anthocyanin. Wherever

bluegrass would like to grow but can't, as in frozen ground, dry ground, intense sunlight, or because of injury to growing leaves, it has a tendency to develop this purple coloring. Uprooted rhizomes become pink at the tips or occasionally for their full length. This is especially noticable in Johnson grass (*Sorghum halepense* (L.) Pers.) where the large fat rhizomes often turn a brilliant cerise when dug up and allowed to remain in the sun. Many other species seem to obey a similar compulsion.

Around manure clumps, the grass remains surprisingly green, and bluegrass rhizomes work beneath the clumps with indifference to the cold. The manure insulates the ground and prevents its freezing, thus allowing bluegrass to continue its growth and to build up its reserves. As a result of this advantage, the grass in these clumps gets away to an early start in spring.

Bluegrass leaves produced in December are very short, only an inch or two long. Except where the grass has been kept short, they are lost within the longer fall and summer leaves. When these old leaves die, pastures turn brown. In heavily pastured places, however, the grass is still green and stock still seek the sugar-rich grass. In many places, they are eating cheat seedlings in preference.

Gophers are very active, throwing up mounds overnight, especially in the longer grass areas where the soil is not so solidly frozen. Mice are once again building extensive tunnels in the sod, and when snow melts away, elaborate feeding runs bordered with cut leaves can be found in the shorter grass, ending here and there in large "haystacks" of reserve food.

Most fall rhizomes have turned up and now rest at the surface of the ground, though a few have been caught underground in the frozen soil. Tillering is still occurring, although the new shoots take several weeks to become large enough to be seen outside the retaining sheaths of their axillant leaf. Even more important than tillering, however, is the beginning of flower initiation. This process began on a few early plants last month, but is now general. A careful examination of the growing point shows a slight accumulation of extra plant segments at its tip, and it is from these that the panicle will develop. So it is that preparation for June pastures, full of waving bluegrass, is made even during this cold month half a year in advance.

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Explanation of Plate

PLATE 1

Fig. 1. January. On a pasture hill near the top, rooting hogs have defined the contact of a limestone and shale bed. Seepage along the contact favors their activity. Resulting changes in the vegetation will mark this contact for some time.

Fig. 2. January. Gilts in an orchard-grass pasture that was not mowed last summer beat paths among the resulting tussocks.

Fig. 3. February. During periods when snow and ice cover the ground horses feed on tall grass preserved in manured or weedy areas. There they can easily scrape the snow away with their hooves.

Fig. 4. February. Rank grass in orchards provides cover for cottontails. For sustenance, however, the rabbits prefer special spots where the grass is short and deep green. These spots usually show evidence of having received applications of urine. They are often grazed completely bare, roots, rhizomes and leaves all being consumed.

Fig. 5. March. Urine applied in a circle around this post in fall resulted in complete utilization of all grass, including subterranean parts, by mice. Even the post was eaten where urine had fallen on it.

Fig. 6. April. Old gopher mounds of last fall are partly covered with grass, but new ones remain barren and spring winds whiten them. These mounds, especially the spring diggings, provide opportunity for weed seeds to germinate, but also produce grass which is darker green, productive, and preferred by stock.

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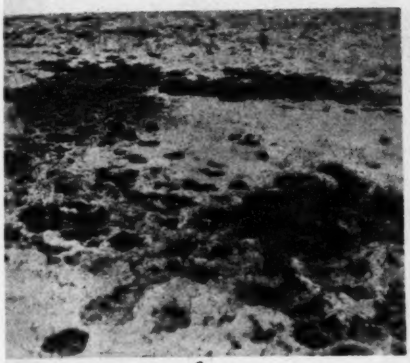

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ETTER—BLUEGRASS PASTURES

Explanation of Plate

PLATE 2

Fig. 7. March. At this time of year the pattern of horse grazing is very apparent. Rank grass remains uneaten while small areas are consistently grazed. These spots received continual applications of urine and remained green all winter.

Fig. 8. April. Stems of last summer's purpletop stand in the new rank grass of spring. When temperatures rise sufficiently to encourage molds and mildews, these stems will drop into the surrounding grass.

Fig. 9. April. Stock do not graze the rank grass round clumps of their own manure and rough areas thus appear in closely grazed pastures. Where cows and horses are grazed together these roughs are not so apparent since no prejudice seems to exist for grass contaminated by droppings of other animals.

Fig. 10. May. The spots of darker and taller grass in this picture received urinations from steers during fall and winter. The resulting grass growth is more nutritious and is preferred by stock. This pasture has not yet been grazed.

Fig. 11. June. When stock are turned in on a pasture such as that in fig. 10, they seek out the urine spots and consume the grass that grows there.

Fig. 12. June. Horses graze limited areas intensively. Under heavy grazing pressure these areas gradually expand. Urinations which burn the grass are concentrated near the periphery of grazings. The dead grass will be replaced by rich weeds and clover which will be grazed closely. Nutritious bluegrass will soon invade the spots and restore the turf.


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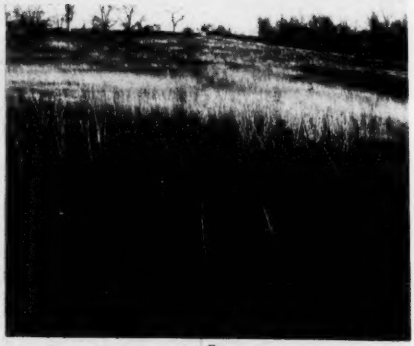
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ETTER—BLUEGRASS PASTURES

Explanation of Plate

PLATE 3

Fig. 13. June. When horse and sheep graze together stable rough areas are built up where horse manure accumulates. Sheep, like horses, prefer short grass. As grazing pressure increases rough areas are gradually whittled away.

Fig. 14. June. This illustration shows the effects of urine on the vegetation of a lawn. Not only does the grass thrive in the right-hand plot, but weeds are eliminated. Application here was about two-thirds gallon per square yard and was applied in June, the previous year, on moist soil.

Fig. 15. June. Mowing of bluegrass pastures commences. The heavy swaths will soon disappear beneath long summer leaves, but earlier mowing would have been desirable and would have maintained the food value of the grass at a higher level.

Fig. 16. June. In the swales of an old hog pasture squirrel-tail grass heads out. This grass often causes mouth injuries to stock that consume it in hay.

Fig. 17. June. Cattle turned into a new pasture in June sought first the rank growth of weeds that had grown up in areas where hogs had fed and urinated. The lamb's-quarters in the picture was cleaned out as were other weed species.

Fig. 18. June. Chicory is a bad pasture weed in some parts of Missouri. It can be controlled to a considerable extent by grazing it in spring since it is highly palatable then. Paddock in the rear was not grazed in spring at all while paddock in foreground was grazed during April. Grazing chicory while it is in the rosette stage weakens it and reduces the height of the coarse flowering stems.

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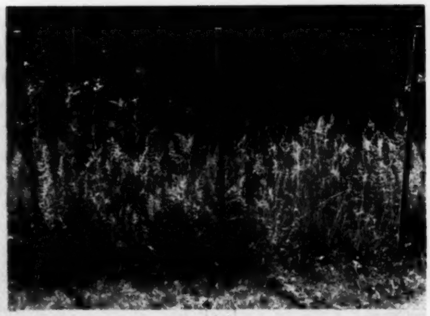

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ETTER—BLUEGRASS PASTURES

Explanation of Plate

PLATE 4

Fig. 19. July. Gopher mounds in rank pastures are often indicated at a distance by a white growth of annual fleabane which germinates in the disturbed soil.

Fig. 20. August. Rabbits are choosey about where they graze. This small spot of crabgrass was grazed into the dirt. The grass was visibly darker green and had apparently benefitted from urine of some species.

Fig. 21. July. Quail use gopher mounds for dusting places.

Fig. 22. September. The time to mow is critical in pasture management and it varies with the species. In foreground a field of timothy and lespedeza was mowed while timothy heads were young and green. In distance where fall herbage is much inferior, mowing had been delayed till July.

Fig. 23. October. In late summer and fall foxtail grass comes into rich heavily grazed pastures. For a while it provides some good midsummer grazing, but, when seeding, is unpalatable. In fall, hungry stock invade the old foxtail and beat it to the ground.

Fig. 24. November. Urine has a striking effect on bluegrass noticeable in both fall and spring. In this picture, it is shown that this effect depends on time of application. Grass in the left plot was given urine in late August; on the right a similar application in late September. There was no visible effect from the earlier application.

Fig. 25. December. Late summer rains softened the soil and unringed sows uprooted the turf. If this pasture were disced and harrowed slightly in early fall it would largely recover. If allowed to go into spring in this condition it will be covered with weeds.


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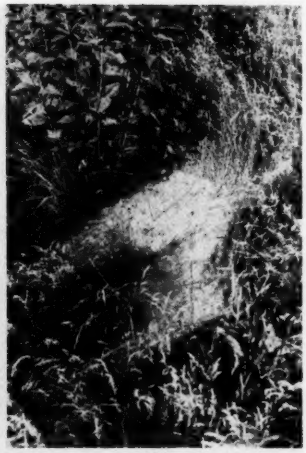
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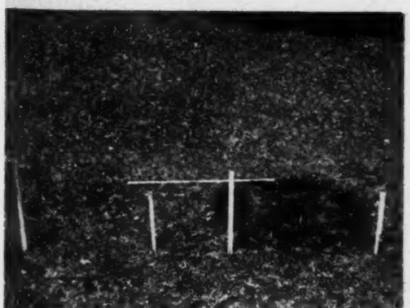
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ETTER—BLUEGRASS PASTURES

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THE POPCORNS OF TURKEY

EDGAR ANDERSON, *Missouri Botanical Garden*

AND

WILLIAM L. BROWN, *Pioneer Hi-Bred Corn Company*

The special significance of popcorns in the history of maize has been recognized by many students of that perennially fascinating problem (see, for instance, Sturtevant, 1894, Mangelsdorf, 1948). To scientists at large, however, the classification of popcorns and the description of the various ways in which they are used have been matters of such little moment that we were eventually driven to making our own world survey of popcorns and their uses (see Anderson and Cutler, 1950, for a general discussion). It was not until a decade of research had taught us to inquire in some of the most unlikely places that we learned (through Volney Jones) that popcorn is commonly used throughout Turkey and is a characteristic feature of many Turkish villages. At the very moment when we were endeavoring to have a comprehensive collection made for us there, Dr. Jack Harlan returned from that country with a collection of economic plants made for the Division of Plant Exploration and Introduction of the United States Department of Agriculture. Fifty-four collections of popcorn made by Dr. Harlan and his collaborators form the basis of the following report. We are indebted to Dr. Harlan for various observations supplementing the unusually complete data turned over to us by the Department of Agriculture, and to Dr. M. M. Hoover and his staff of the Regional Introduction Station at Ames, Iowa. It is a pleasure to acknowledge the efficiency and courtesy of this entire organization. We were welcomed to the increase plots in good weather and in bad, our attention was called to other collections of possible significance, and we were supplied promptly with viable seed of all the cultures we wanted to grow. For a few varieties of particular interest pertinent information was quickly produced from the files, and remnant seed of the original collections was made available to us.

The 54 Turkish popcorns collected by Dr. Harlan were grown in the experimental plots of the Pioneer Hi-Bred Corn Company at Johnston, Iowa, 20–30 plants being grown of each collection. A few varieties of particular interest were grown in replicate, and flint varieties and flint-dent mixtures from Dr. Harlan's collections were available for comparison in another plot. Each variety was scored for morphological uniformity, for season, for tassel type. Detailed measurements were taken on plant height, ear height, ear number, number of leaves above the ear, leaf length, leaf width, tassel exsertion, internode length and internode pattern, the width of the central spike of the tassel, glume length, the number of tertiary branches on the lowermost secondary branch of the tassel, the number of branchlets of the fourth order (if any), the number of secondary tassel branches, and the pubescence of the leaf sheath. At harvest time the plants were scored for husk number, for number of apparent nodes in the shank (the difference between these two numbers represents the number of condensed [telescoped] nodes of the

shank), shank length, shank width, kernel row number, kernel thickness, pith diameter, basal enlargement of the ear, pointing of the kernel, and color of pericarp and endosperm. At silking time regulation photographs of representative plants were made against a measured background. "Inclusive" herbarium specimens (Anderson, 1951) were made as a permanent record of each collection, each specimen including a photograph of the entire plant against a measured background and pressed central spikes and lower tassel branches.

Sporocytes of each culture were pickled in aceto-alcohol and smeared in the cytological laboratory. The number of chromosome knobs (a variable and diagnostic feature in maize—see, for instance, Mangelsdorf and Cameron, 1942) were determined and wherever possible knob positions were worked out. The results of these various measurements and scores are presented in Tables I and II. Photographs of representative plants are shown in pls. 5 and 6.

As soon as the collection began to tassel it was clear that maize is as heterogeneous a mixture in Turkey as are many other crops in that area (see Harlan, 1951). The variation within collections and between collections exceeded that in any of the collections of exotic maize from various parts of the world which we have had under observation. Three extreme types and three mixtures and intermediates between these extremes were apparent in the collection. One of these extremes was a popcorn identical with the variety known as Japanese Hull-less Popcorn. Since it came from Ankara, the capital city, and since most of the intermediates between it and the other two types came from the vicinity of Ankara or Istambul, the older capital, it probably represents a comparatively recent introduction into Turkey. It was strikingly different from the other two extremes. It had pubescent leaves, a heavy tassel with an extremely thick central spike, and the ear was elliptical in cross-section with a high number of rows of kernels, all of these features being characteristic of the variety Japanese Hull-less.

The other two extreme types were unlike popcorns commonly grown in the United States, and the two extremes, though connected by various intermediates, were quite unlike one another. One was very early to mature; the other was very late. The early type was short, with an exserted tassel, large glumes, and stiff upright tassel branches. Characteristically, the type had a low number of chromosome knobs, usually from none to three with either no knob on chromosome No. 6, or merely one small one. The late extreme was tall with numerous short internodes above the ear, which was borne high on the plant. The tassel was characterized by small glumes and lax branches, at maturity even the central spike remaining drooped over. The tassel was so included in the sheaths of the upper leaves that the lowest tassel branches were never completely free from the sheath of the uppermost leaf. Characteristically, it had seven to eight chromosome knobs, including two on chromosome No. 6 and one on No. 8. All these facts are set forth in the tables and the plates. Figures 1 and 2 show diagrammatically, but to scale, representative plants from the three most extreme collections of the two types.

The early extreme bears no close resemblance to any known race of maize though it is vaguely similar to several. It is rather like a somewhat degenerate form of the Northern Flint corns which were once characteristic of eastern North America. It is shorter and earlier than most of them, with somewhat smaller ears, higher row numbers on the average, and without the more or less enlarged base to the ear which is one of their most distinctive features.

The late extreme, on the other hand, belongs to a group of little-known popcorns with an intriguingly peculiar distribution. They are commonly grown by various aboriginal tribes along the borders of China and India; they were in early prehistoric times the prevailing type of maize on the coast of Peru and Chile; and they are still to be found here and there in various out-of-the-way places in South America. We received some years ago from Lorenzo Parodi, of Argentina, a popcorn of this general type and have a few scattered collections from Peru, Chile, and Colombia. Mangelsdorf and Oliver (1951) described and illustrated one from Caldas, Colombia. The collections from Turkey agreed with these Asiatic and South American popcorns in various technical characteristics of the inflorescence (see Alava, 1952)—in their knob numbers, the numerous ears high on the plant, the short upper internodes, and the drooping, included tassels. In its height, leaf shape, etc., the collection made by Harlan at Samsun was similar to varieties we have grown from the mountains of Siam, from the Naga tribes of Assam and from the Lushai Hills. Not only did it agree in general with these Oriental and ancient South American popcorns; with a popcorn collected in the mountains of Nepal (P.I. #166,162 called to our attention by Dr. Hoover), it was virtually identical. The collections from Nepal and from Turkey differed not as much as would two strains of any open-pollinated (i.e. non-hybrid) popcorn variety (such as Japanese Hull-less or South American) grown in the United States.

The three extreme types described above were apprehended by repeated study of the plants in the breeding plot. The exact association of characters was worked out more objectively by means of pictorialized scatter diagrams. One of these is presented in fig. 3. It has been set up to demonstrate the relationship for the seven characters which best differentiate the early flint-like popcorns from the late "Asiatic" extremes. As fig. 3 demonstrates, there is in the Turkish collections an over-all association for these seven characters, tassel exsertion, percentage of total height in the internodes above the ear, glume length, chromosome knob number, shank width, plant height, and ear height. At the upper right-hand corner of the diagram are the Asiatic extremes. As the diagram demonstrates, they are all plants with ears high on the plant, the internodes above the ears being proportionately short. They have narrow shanks, small glumes, and high knob numbers. At the lower left-hand corner of the diagram are the opposite extremes, a more variable lot. They tend to be short, low-eared plants, with exserted tassels and proportionately long internodes below the tassel. They have wide shanks, long glumes, and few or no knobs on their chromosomes. It will be seen that though the Asiatic extremes seem to be somewhat set off from the rest there is a gradual

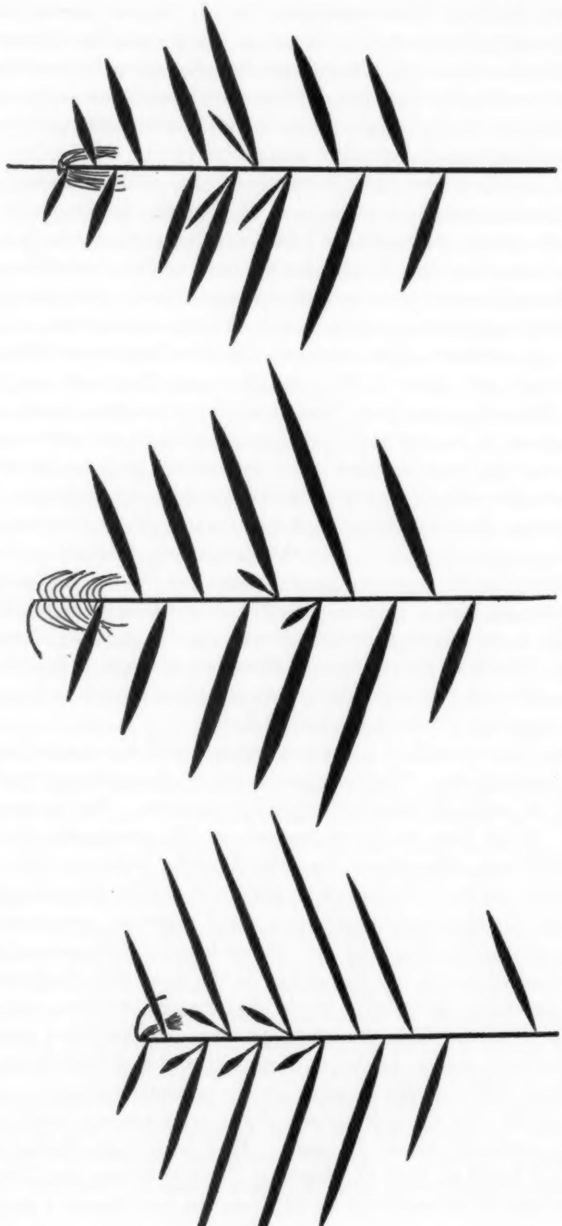

Fig. 1

Three examples of the "Asiatic" race of popcorn, highly diagrammatic but exactly to scale (× 1/25). The lengths of the internodes, of the leaves, of the shanks, and of the branches of the tassel are all to scale, and the shape of the tassel is copied from photographs of fully mature tassels. Each diagram represents a different collection. Note the short internodes, the drooping included tassels, and the multiple ears high on the plant.

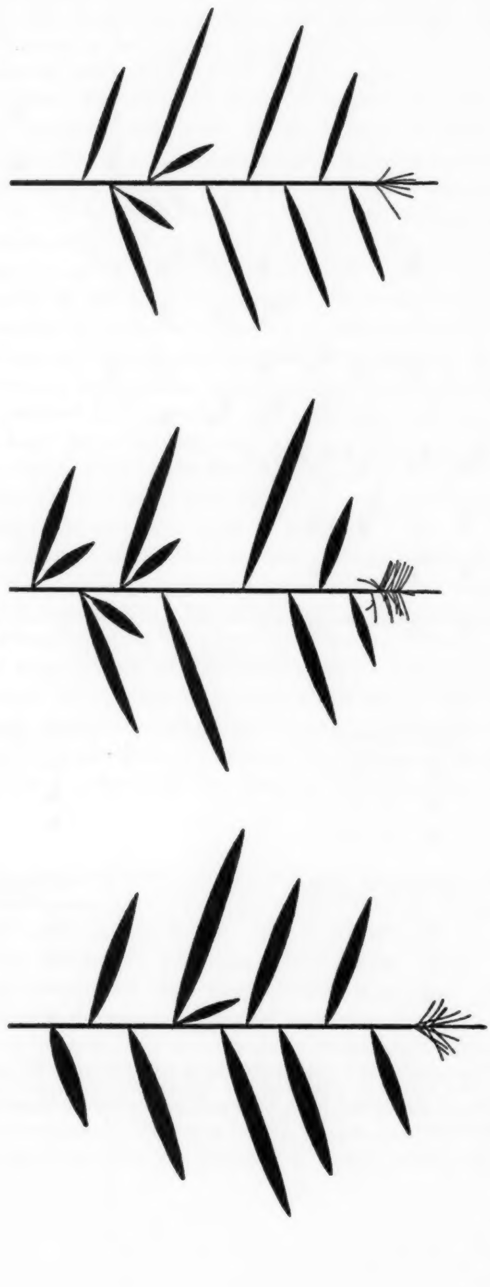

Fig. 2

Three examples of the "Aegean" race of popcorn, to the same scale and prepared in the same way as fig. 1. Note the exserted tassels, the longer internodes at the upper part of the plant, and the low ears.

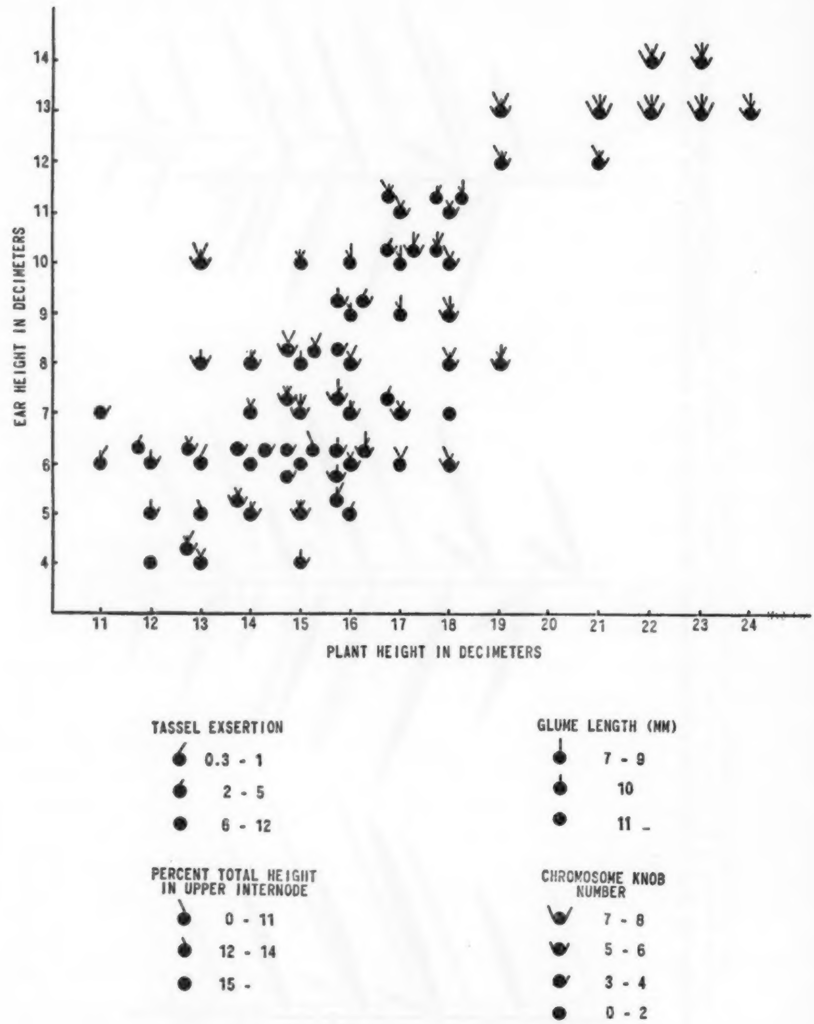

Fig. 3. Pictorialized scatter diagram illustrating the variation in Harlan's collection of Turkish popcorns for seven characters. Each dot is a diagram of a single plant for each collection, the plant having been chosen in the field as most representative for that particular collection. Further explanation in the text.

transition from one extreme to the other. The diagram presents an exact picture of the way in which two diverse races of maize have been brought together and have intermingled, forming a variable set of intermediates. Some of these are extreme recombinations in which characters of one race have been combined with characters from the other. For the whole group of varieties, however, there can be demonstrated the continuing association, *on the average,* of those characters which went in together. For those not familiar with the recent work on races of maize it should be pointed out that just such a mingling of correlated variables is characteristic of maize. It has been shown for Mexico by Wellhausen, Roberts, and Hernandez in collaboration with Mangelsdorf (1951, 1952), who have greatly extended the preliminary studies of Anderson and Cutler (1942) and Anderson (1946). For the maize of the American corn belt where purposeful mixing of two races has been carried on intensively, Brown and Anderson (1947) were able through these correlations to work out the history of the mingling by these indirect methods before carrying on the historical and archaeological research which proved that it had indeed occurred in just such a way (Anderson and Brown, 1952). There can be little doubt then that the heterogeneous popcorns of Turkey were largely derived from the mingling of popcorns from the two widely different races of maize, the resulting mixture being made somewhat more diverse by the comparatively recent addition of still other types of popcorn.

After the racial affiliations of the 54 collections made by Dr. Harlan had been worked out, their distribution in Turkey was determined from his collecting notes. The resulting picture is a simple one. The Asiatic race in its purest form is characteristic of the mountainous areas in northeastern Turkey. The other race is characteristic of the Aegean shores of Anatolia and we are accordingly referring to it as the Aegean race. It is possible to turn the pictorialized scatter diagram of fig. 3 into a crude sort of index running from 0 to 14. By plotting these index numbers in four grades it is possible to demonstrate the mingling of the Aegean and Asiatic races of popcorn as reflected by Dr. Harlan's collections (fig. 4).

Conclusions:

From the evidence presented above we conclude that popcorn is widespread in Turkey. Though heterogeneous there even for maize, it can be assigned to two provisional races, the Aegean and the Asiatic. The former is commonest along the coast, the latter in the northeastern mountains. Most of the popcorns of Turkey are various intermediates between these two extremes, occasionally modified by more recent introductions of modern commercial varieties.

In the above report there is little or no evidence to indicate when or where or by whom these popcorns were introduced into Turkey. To answer such questions we have begun a series of ethnological, linguistic, and historical inquiries. These investigations have proceeded to the point where we are confident that though the problem is a complex one, it is not chaotic. It seems probable to us, in the

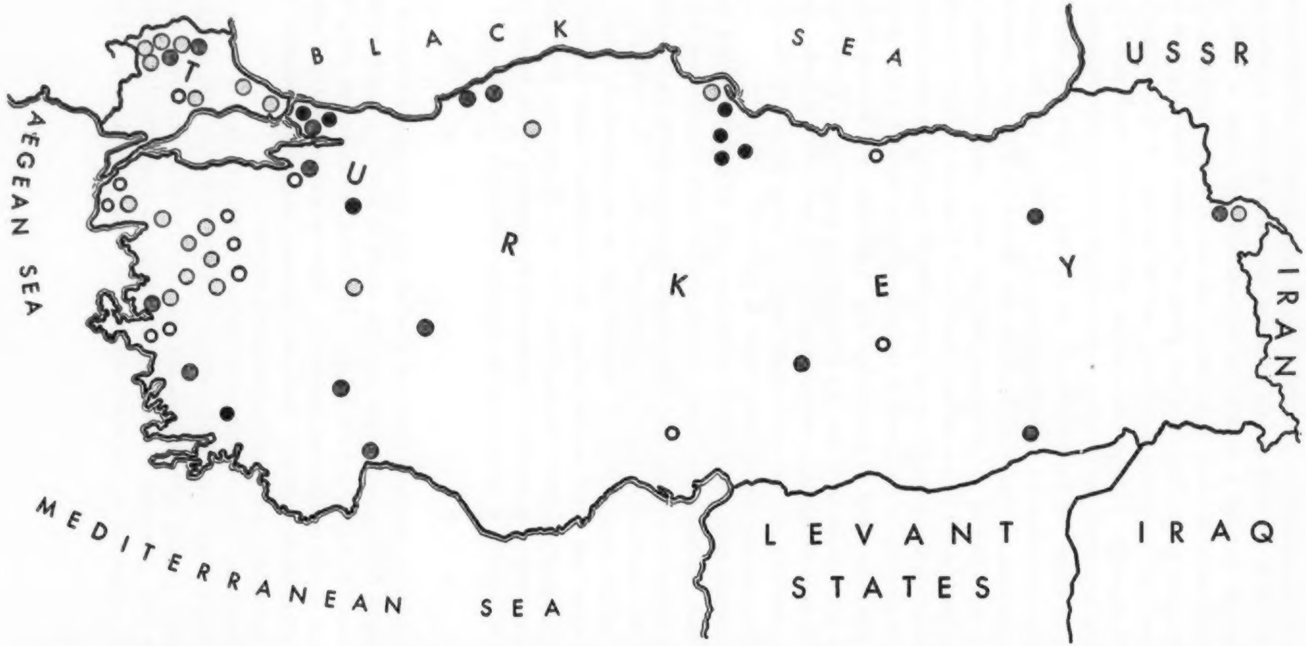

Fig. 4. Distribution of the original collections made by Dr. Harlan and diagrammed in fig. 3. The numerous collections in and around Ankara, the capitol city, have been omitted. The values of fig. 3 have been turned into a crude index running from 0 for typical "Aegean" varieties to 14 for typical "Asiatic" varieties. Solid black dots represent collections most like the Asiatic extreme (those in the upper right-hand corner of fig. 3); open circles, the most extreme Aegean types; lightly stippled dots, intermediates resembling Aegean; heavily stippled dots, intermediates resembling Asiatic race.

light of all the evidence, that the Asiatic and the Aegean popcorns were brought to Turkey at different times, and by different routes. Further discussion must be postponed until other evidence can be presented.

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TABLE I

Turkish popcorns listed in the order of their official plant introduction numbers. For each collection there is given the place where the seed was collected, the season of maturity, the variability of the plants grown from that collection, the height of the plant in decimeters, the height of the uppermost ear in decimeters, the number of ears, the length of the uppermost internode in centimeters, the length of the male glume in millimeters and the Index number on a seven-fold index with values of 0 for extreme "Aegean" types and of 14 for extreme "Asiatic" types (further explanation in the text).

Plant Introduction Number	Place	Season	Variability	Height of plant in dm.	Height of ear in dm.	Number of ears	Length of uppermost internode in dm.	Length of glume in mm.	Index Number
164,994	Cayirhan, Ankara	Mid	Uniform	14	8	2	2.3	10	3
165,036	Nallihan, Ankara	Mid	Uniform	15	8	2	2.4	10	1
165,057	Beypazare, Ankara	Mid	Variable	16	9	2	1.8	11	1
167,030	Kirik-Khan, Hatay	Late	Variable	18	11	2	2.2	12	5
167,947	Kulak, Balikesir	Mid	Uniform	15	5	3	1.9	10	5
167,948	Bursa	Early	Uniform	15	6	2	2.7	12	0
167,949	Balikesir	Early	—	16	6	2	1.9	13	3
167,963	Bucak, Burdur	Late	Uniform	18	9	2	1.8	8	8
167,967	Osman Buku, Aydin	Mid	Uniform	15	7	2	1.7	9	8
167,983	Koycegiz, Mugla	Very Late	Uniform	23	15	2	1.6	9	12
167,989	Akhisar, Manisa	Mid	—	16	9	2	2.2	9	2
168,000	Istanbul	Mid	Uniform	16	8	2	2.1	9	4
168,006	Kirklareli	Mid	Uniform	15	10	2	2.0	10	4
168,007	Kirklareli	Mid	Uniform	16	10	1	2.1	9	4
168,008	Kirklareli	Mid	Uniform	18	11	2	2.1	9	5
168,016	Tekirdag	Mid	Uniform	15	6	2	2.4	10	1
168,017	Tekirdag	Mid	Uniform	15	4	2	2.2	10	2
168,019	From a seed store	Early	—	16	9	1	2.3	10	2
168,027	Ayvacik, Canakkale	Early	—	14	6	2	2.1	12	0
168,032	Edremit	Mid	—	16	6	2	2.4	9	2
168,033	Balikesir	Early	Uniform	12	5	2	2.1	10	2
168,039	Kulak, Balikesir	Early	Uniform	15	6	1	1.3	11	2
170,877	Manisa	Mid	Uniform	14	6	2	2.5	11	1
170,879	Soma, Manisa	Early	Uniform	13	4	1	2.1	12	2
170,880	Istanbul	Mid	—	13	6	2	2.7	12	2
170,881	Cayirova, Kocaeli	Mid	Uniform	18	10	3	1.6	11	6
171,896	Inceoglu, Bartin	Late	—	13	10	3	1.4	10	8
171,912	Tokat	Very Late	Uniform	22	13	3	2.5	9	14
171,915	Niksar, Tokat	Very Late	Uniform	23	13	3	1.2	8	14
171,917	Niksar, Tokat	Very Late	Uniform	22	15	3	1.0	10	13
172,600	Igdir, Karahisar	Mid	—	13	8	2	2.0	10	3
173,830	Malatya	Mid	Uniform	14	6	2	2.2	11	1
174,414	Mardin	Late	Uniform	17	11	2	1.7	11	6

175,976	Biga, Canakkale	Early (Mid)	—	11	7	2	2.2	13	1
175,978	Biga, Canakkale	Early (Mid)	—	13	4	2	1.8	10	5
176,801	Erzincan	Mid (Late)	—	15	7	2	1.7	10	5
176,804	Ayfon, Karahisar	Late		17	6	2	1.5	12	5
177,114	Araplar, Ayvalik, Balikesir	Early	Uniform	11	6	2	2.0	10	3
177,583	Ankara	Late	Uniform	15	8	2	2.2	11	6
177,598	Ankara	Early	—	12	6	2	2.0	11	2
177,622	Ankara	Mid	—	15	8	2	2.0	9	3
177,624	Ankara	Mid	—	18	8	2	1.5	10	7
177,625	Ankara	Early	—	16	5	1	2.8	11	1
177,626	Ankara	Late	Uniform	15	5	1	2.0	10	—
177,628	Ankara	Late	—	17	7	1	2.3	12	5
177,631	Ankara	Mid	—	16	6	1	2.1	10	3
177,637	Ankara	Late	—	16	7	2	2.5	10	3
177,641	Ankara	Mid	—	16	7	2	2.8	11	5
177,643	Ankara	Mid	—	18	7	2	2.8	12	1
179,127	Kalecik, Ankara	Mid	—	16	5	2	2.7	10	3
179,131	Alpagut, Sakarya Eskisehir	Late	—	19	13	3	1.9	10	11
179,566	Altinova, Ayvalik, Balikesir	Early	Uniform	12	6	2	1.8	10	1
179,568	Araplar	Early	Uniform	13	5	2	1.7	11	1
179,579	Sehir, Sebin Karahisar, Giresun	Mid	—	13	7	2	1.6	12	—
182,324	Bolce Agac, Manyas, Balikesir	Early	Variable	12	4	2	1.8	11	0
182,326	Elbistan–N.E. of Tarsus	Mid	—	19	8	1	2.2	9	9
182,327	Igdir, Karahisar	Mid	—	17	11	1	1.3	10	6
182,785	Gemlik, Barsa	Mid	—	18	10	2	1.4	9	7
183,750	Karga ili, Kastanou	Mid	Uniform	18	11	2	1.8	10	4
183,751	Karet-Satranbolu, Zonguldak	Late	—	24	13	2	1.8	9	11
183,756	Kozam, Adana	Mid	—	15	6	2	2.9	11	1
183,764	Kilic, Kesan, Edirne	Early	—	14	7	2	2.0	11	2
183,771	Edirne	Mid	—	14	5	1	2.3	10	3
183,783	Lalapasa, Edirne	Early	Variable	14	5	2	1.9	12	4
183,787	Ankara (near)	Mid	—	18	6	1	1.9	12	6
183,790	Manisa	Mid	—	16	6	2	2.4	11	5
183,798	————	Mid	Variable	16	8	1	2.8	11	1
185,045	Elmali, Antalya	Late	—	17	10	2	2.5	9	4
185,063	Bafra, Samsun	Mid	—	13	6	2	1.7	11	3
185,073	Akesehir, Kohya	Late	—	16	9	2	1.9	11	5
167,030	Misifite	Late	—	17	9	2	2.1	9	4
167,030	Misifite, from farmers at Kirik-Khan, Hatay	Late	Variable	17	10	2	1.7	8	8
170,881	Cayirova, Kocaeli	Late	—	19	12	2	1.4	10	9
170,881	Cayirova, Kocaeli	Late	—	21	12	3	1.1	10	9
171,904	Seed dealer in Samsun	Very Late	Uniform	19	12	3	—	10	14

TABLE II

Numbers and positions of chromosome knobs for the collection of popcorns from Turkey. The numbers at the left are the official plant introduction numbers of the Bureau of Plant Exploration and Introduction. Numbers 1 to 10 in the heading at the right refer to the 10 chromosomes of *Zea Mays* as recognized by maize cyto-geneticists. The final column, "B", records the numbers of "B" chromosomes, if any. Where no number is given, there were no "B" chromosomes. —1 indicates a knob on either one of two chromosomes. "s" = small. "T" = terminal.

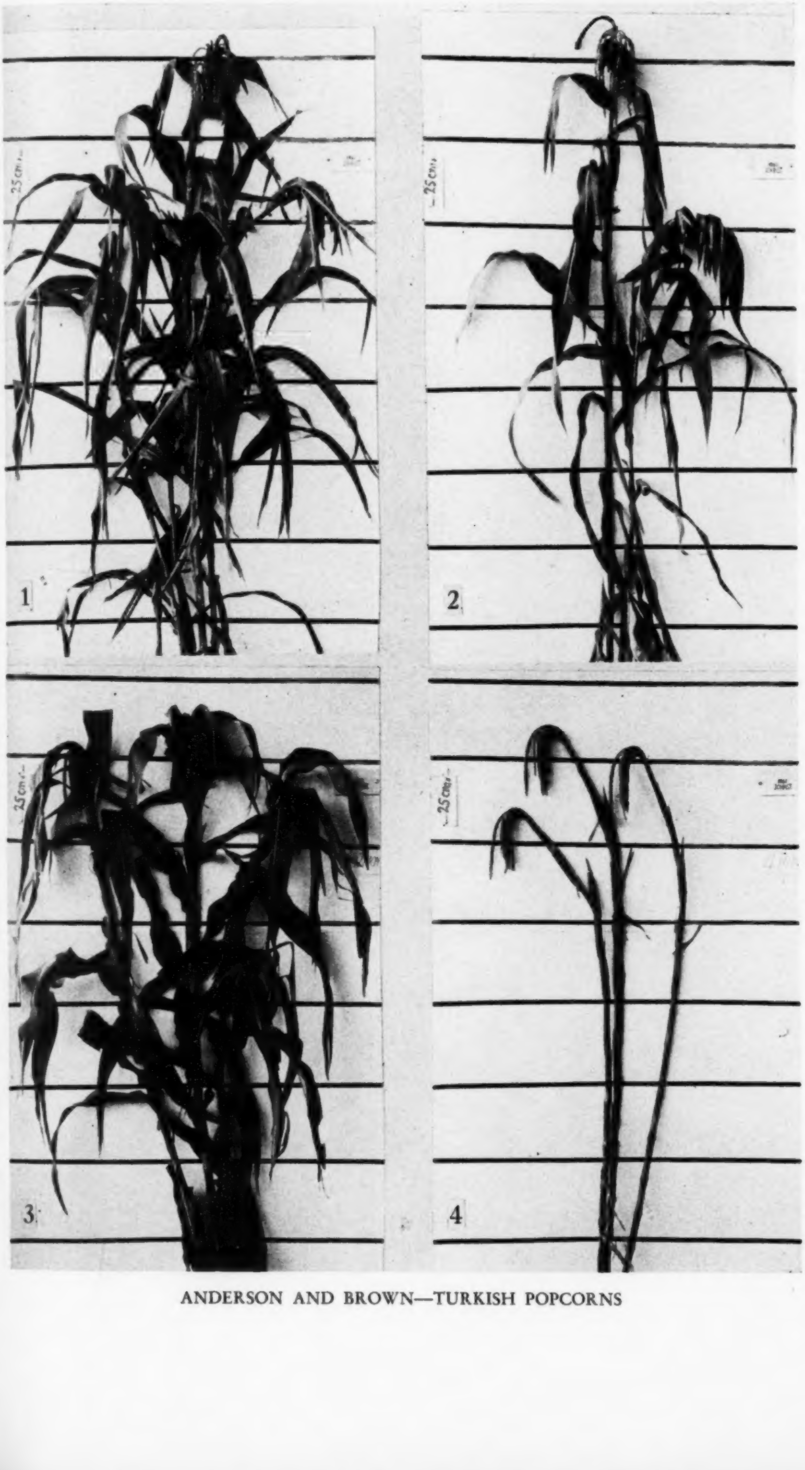
Number	Number of knobs	Knob position										
		1	2	3	4	5	6	7	8	9	10	B
P. I. 164994	4						2	—1	—	1T		
P. I. 165036	1						1					
P. I. 165057	4						1	1	1	1T		
P. I. 167030	4				1		1	1		1T		
P. I. 167947	5		1				2	1		1T		
P. I. 167948	2						0	1	1	0	0	
P. I. 167949	3						0	1		1T		
P. I. 167963	6		1		1?		2	1	1			
P. I. 167967	5	0	1	1	1	1	0	—1	—			
P. I. 167983	6–7						2	1	1	1T		
P. I. 167989	2						0		1	0	0	
P. I. 168000	4		1				0	—1	—	1T		
P. I. 168006	1				1		0					
P. I. 168007	2					1?		1				
P. I. 168008	3						0		1	1T		
P. I. 168016	3						1	1		1T		
P. I. 168017	4			1			1	1		1T		
P. I. 168019	3						1	1		1T		
P. I. 168027	1						1					
P. I. 168032	3						1	1	0	1T	0	
P. I. 168033	2					1	0	1				
P. I. 168039	0											
P. I. 170877	3						1		1	1T		
P. I. 170879	1						0			1T		
P. I. 170880	3		1				0	1	1			
P. I. 170881	4						2	1	1			
P. I. 171896	5	1s	1?				2			1T		2
P. I. 171912	8	0		1	0	1?	2	1	1	2	0	
P. I. 171915	7–8	1s					2	1	1			
P. I. 171917	7?						2	1	1	1T	0	
P. I. 172600	6	1s					1	1	2	1T	0	
P. I. 173830	3	0	1s				0		1	1T	0	
P. I. 174414	3		1		1		0	1	0	0	0	
P. I. 175976	4		1				1	1		1T		
P. I. 175978	3						1	1		1T	0	
P. I. 176801	6		1				2	1	1	1T		
P. I. 176804	1				1		0					
P. I. 177114	2					1?				1T		
P. I. 177583	5	1?					2	1	0	1T	0	
P. I. 177598	3					1	0	1		1T	0	
P. I. 177622	2							1		1T		
P. I. 177624	4						1	0	1	1T	0	
P. I. 177625	2	0	1s				0		1	0	0	
P. I. 177626	2			1?			0	1				
P. I. 177628	6	0	1	0	1	1	2	1?		0	0	
P. I. 177631	5		1		1		2	1				
P. I. 177637	3		1		1		0	1		0	0	
P. I. 177641	5						1	1	2	0	0	
P. I. 177643	2						1	0	1	0	0	
P. I. 179127	1									1T		
P. I. 179131	5		1		1		0		1	1T		

Number	Number of knobs	Knob position										
		1	2	3	4	5	6	7	8	9	10	B
P. I. 179566	2					1	0			1T	0	
P. I. 179568	2							2				
P. I. 182324	2						0	1		1T	0	
P. I. 182326	4						1	1	2			
P. I. 182327	2						0	1		1T		
P. I. 182785	1		—1	–								
P. I. 183750	4			1?						1T		
P. I. 183751	5?									1T		
P. I. 183756	4						2	1		1T		
P. I. 183764	1							1				
P. I. 183771	3						0		2	1T	0	
P. I. 183783	5			1		1	0	0	2	1T	0	
P. I. 183787	5						2					
P. I. 183790	5					1	0	1	1	2	0	
P. I. 183798	4		1	1			1		1			
P. I. 185045	3						1			1T		1
P. I. 185063	3L						1	1		1T		
P. I. 185073	2?							1		1T		
P. I. 167030	2									1T		
P. I. 167030	5L						2	1	1	1T	0	
P. I. 170881	3L						1	1	1			
P. I. 170881	3						1	1	1			
P. I. 171904	8			1	1	1	2	0	1	2	0	

Explanation of Plate

PLATE 5

Four plants of Dr. Harlan's collection from Samsun, Turkey, photographed against a measured background, at the time when the tassels were actively shedding pollen. Note the drooping tassels, barely exserted from the upper leaves, the ears high on the plant. Specimen No. 4 has had its leaf blades and most of its leaf sheaths removed. The lines in the background are 25 cm. apart.



ANDERSON AND BROWN—TURKISH POPCORNS

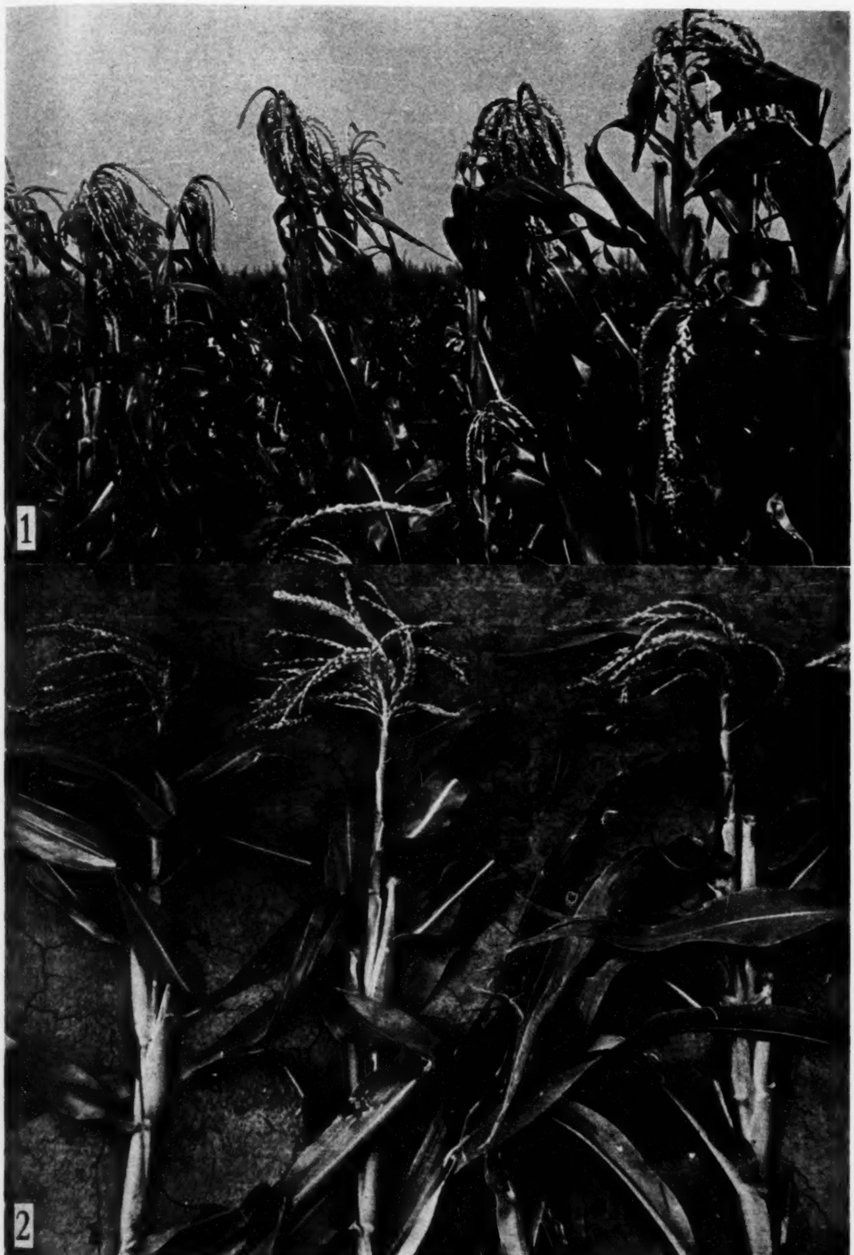
Explanation of Plate

PLATE 6

The same "Asiatic" popcorn of pl. 5, photographed in the field at harvest time.

Fig. 1. Plants photographed in the experimental plot. Note the ears high on the plant, the drooping tassels, and the plant-to-plant uniformity. These plants were grown from remnant seed actually collected in Turkey. The uniformity of this variety is characteristic of collections made both in Nepal and in Turkey.

Fig. 2. Three plants from the same row as those in fig. 1, laid down on the earth of the breeding plot. Note the multiple ears, high on the plant, the leaves continuing to the very base of the tassel, the drooping tassel branches, the slender stem, and the short silks. These are all characteristic of Asiatic popcorns.



ANDERSON AND BROWN—TURKISH POPCORNS

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A PRELIMINARY SURVEY OF THE MILPA SYSTEM OF MAIZE CULTURE AS PRACTICED BY THE MAYA INDIANS OF THE NORTHERN PART OF THE YUCATAN PENINSULA

R. A. EMERSON

Foreword

In January and February of 1935, Professor R. A. Emerson, of Cornell University, and Mr. J. H. Kempton, then of the U. S. Department of Agriculture, studied maize farming among the Maya Indians at the request of the Carnegie Institution. The following report, circulated in mimeographed form under Dr. Emerson's name, is one of the tangible results of this preliminary survey. Though it has been cited in at least two bibliographies its very existence has been unsuspected by many students of maize. We are indebted to Mrs. Ida K. Langman, of the Academy of Natural Sciences of Philadelphia, for supplying us with a copy, and to Dr. H. E. D. Pollock, of the Department of Archaeology of the Carnegie Institution, for granting permission to reprint the document.

Up until the time of his death Dr. Emerson was the heart and center of research in maize genetics. He was not only the outstanding authority; most of the other workers had either been trained under him or had been closely associated with the work of his laboratory. Mr. Kempton, on his part, has been identified with much of the research on maize which was carried on in the U. S. Department of Agriculture and had taken the lead in studying maize and its relatives in Latin America.

During the last decade, Mexico, in general, and Mexico's pattern of growing maize, in particular, have changed at an ever-accelerating rate. Dr. Emerson's report, though preliminary and informal, gives us an over-all picture of maize in an out-of-the-way part of Mexico fifteen years ago as seen through the eyes of the greatest maize scholar of his time.—Edgar Anderson.

PURPOSE OF THE SURVEY

In the course of archeological studies of the ancient Maya civilization, conducted by the Carnegie Institution of Washington and other agencies, it has become important to estimate the density of population that could have been maintained by the agricultural system then in use. Is it possible that the Mayas of one or two thousand years ago could have used a more intensive type of agriculture than that employed by Mayas of the present day? Could the fact that large cities and their contributing territories were abandoned, some of them to be rehabilitated only after some hundreds of years, have been due even in part to the inadequacy of the agriculture of these regions? Could a possible decline in the productivity of the agricultural land have necessitated abandonment after a century or more? Was such postulated decline in soil fertility related casually to the system of agriculture in vogue?

It was not so much to find conclusive answers to such questions as these as it was to form an opinion of the possible value of a more thorough and sustained agronomic study as an aid in answering them that a preliminary survey of parts of the former Maya region was undertaken.

REGION COVERED BY THE SURVEY

The survey was conducted under the auspices of the Division of Historical Research of the Carnegie Institution of Washington and under the tutelage of Dr. S. G. Morley of the Chichen Itza project of that Institution. It was begun the latter part of January and continued to the end of February, 1935. The

personnel consisted of Mr. J. H. Kempton of the United States Department of Agriculture, and of the writer. Throughout the study they had the help of an interpreter and usually of a local milpero.

The study of milpas was begun at Piste in the central part of the state of Yucatan near Chichen Itza and about 120 kilometers from Merida. Trips between Merida and Chichen Itza by automobile and by train over different routes, a trip by train from Merida southeast to Peto about 150 kilometers, and another by train from Merida southwest to Campeche about 180 kilometers, afforded glimpses of the western half of the state of Yucatan and the northwestern part of the state of Campeche. From a number of places along these lines of railroad, milpas at distances ranging from a few up to 40 kilometers were visited by automobile, tram-car, mule cart, on horse-back, or afoot. Such points of departure were: Piste, Oxkutzkab, and Peto in the state of Yucatan, and Campeche in the state of Campeche.

TYPE OF COUNTRY VISITED

Topography.—The parts of Yucatan and of Campeche that were visited, as is said to be true of all of the northern part of the Yucatan peninsula, are a low, slightly undulating plain, broken in the southwestern part by ranges of low hills themselves only a few hundred feet above sea level. There is not even a suggestion of a river or brook in all that part of the peninsula visited.

Limestone rock.—The soil is underlaid throughout by a rather soft and porous limestone. Everywhere there appear outcrops of this rock. The sides and tops of small low knolls, often seen to be all rock, and the intervening areas, only a few meters less elevated than the knolls, exhibit many outcrops of rocks. In fact, it is never far from the surface to stratified rock. Although this soft limestone seems to harden on exposure after being taken from quarries, there are abundant evidences of its weathering to produce the usually scant soil. Everywhere exposed rocks are pitted with holes from the size of pin-heads to a meter across and half that deep. Both vertical and horizontal crevices of variable sizes are to be noted greater or less distances apart. Such crevices extend downward for considerable distances, perhaps even to the permanent water table which lies from a few to 50 or more meters below the surface, the distance apparently depending on the relative elevation of the surface. Numerous caves and even large caverns exist. Not infrequently these extend down to or considerably below the water table. When such caverns are open to the surface, they constitute the natural wells, *cenotes*, of the region, upon which the Mayas depend for their water supply.

Soils.—Evidences of the weathering of limestone rocks to produce soil are so universal that one is inclined to speculate on what would have been the nature of the land surface, had these rocks been exposed for ages to the alternate freezing and thawing in latitudes far to the north. Presumably the low plain would have been covered with some meters of fine loam instead of the scant soil covering now seen. And this might have resulted in a very different type of agriculture from that now prevailing.

On the numerous low knolls the soil is seldom more than a few centimeters deep and on many of them soil is seen only in pockets, or crevices in the rock. Crevices seem to be filled with surface soil and humus to considerable depths, as can be readily observed in recently worked stone quarries. Between the knolls the soil may be a half meter in depth, in some places more, and in many places much less than that. The only relatively deep soils observed are those bordering the ranges of low hills in the southwestern part of the area visited. At Oxkutzkab such border soils were said to be as much as five meters deep. The near absence of surface stone and the luxuriant growth and productivity of citrus trees in this region make such an estimate seem not unreasonable. Evidently the heaviest rains have carried down to the plain enough sediment to build up a relatively deep soil at the foot of the hills. Yet, there is little evidence of even temporary waterways on the hillsides and no evidence whatever of brooks paralleling the base of the hills or leading away from them. The water presumably spreads out in a thin sheet over the plain, depositing much of its sediment before disappearing into rock crevices. These bands of deeper soil at the base of the hills are of very minor importance for the region as a whole, for they are seldom as much as a kilometer wide and in many places are very narrow.

The surface soil, to a depth of a few centimeters on land on which the bush has been undisturbed for from ten to twenty years, is made up largely of decaying vegetable matter. During the dry winter season there is a sparse covering of dry leaves, nowhere the heavy covering seen in northern forests. Beneath this layer of leaves is a shallow layer of partly decayed vegetable matter and below that the red or brown loam. Evidently the relatively high temperature and considerable moisture of the region induce such rapid decay of the fallen leaves that no deep layer of decaying vegetable matter ever accumulates.

Climate.—The entire peninsula of Yucatan lies within the tropics, the northernmost part being somewhat below the 22nd parallel of latitude. The rainfall is light in the extreme northern and northwestern parts of the peninsula. Near Merida and along the gulf coast as far south as Campeche, the annual rainfall is said to be not over 18 to 20 inches. At Chichen Itza the annual precipitation approaches 50 inches. The year is divided into two seasons, a summer rainy season of about five months, usually from May to September inclusive but sometimes beginning nearly a month earlier or a month later, and a dry winter season of about seven months from October to April inclusive.

Some of the weather records kept at Chichen Itza for the past nine or ten years were examined. The total precipitation for 1933 was 50.1 inches and for 1934, 46.6 inches. During the five months, May to September, of 1933, 86 per cent of the year's rain fell; during the same months of 1934, only 73 per cent of the annual rainfall was recorded. Of the 730 days of the two-year period, rain fell on 275 days, 185 of them in the two five-month summer seasons. The maximum rainfall for one day, 4.75 inches, occurred in September, 1933. One-half inch or more of rain fell on 56 of the 275 rainy days, and 46 of the 56 were in the May–

September periods. During the two-year period there were 168 days on which .2 inches or less of rain fell, 102 of them having been in the five-month summer seasons.

The mean of the maximum daily temperatures for the years 1933 and 1934 at Chichen Itza was 91.6° F., and the mean of the daily minimum temperatures was 65.6° F. The highest temperatures occurred in March, April, and early May, maximum temperatures of 101°, 103° and 105° F. respectively having been recorded for these months in 1933. When the rainy season begins the maximum temperatures are not as high. Minimum temperatures are lowest during the period from late November to early March. During 1933 the lowest temperature recorded was 47° F., which occurred twice in December; in 1934, 44° was recorded twice in March, and 43° once in December. The lowest temperature on record was 40° F. on January 27, 1935.

Vegetation.—Except for land in crops, the whole of the northwestern part of the Yucatan peninsula is covered by "bush". This consists for the most part of trees and of vines which cling to the trees. In land not in crops for ten to twenty years, the dominant trees are 10 to 15 meters high and 10 to 20 centimeters in diameter. Under these are many smaller trees that have died or been suppressed by the shade of the larger trees. Relatively few annual weeds and almost no grasses are seen in any heavy bush. Both of these occur, however, along trails and in the more open places in the bush.

In bush of only a few years' growth, many annual weeds and small vines are to be seen. Among these are amaranths, numerous composites, and several kinds of bindweed. As the trees grow and shade the ground more and more, these weeds are less and less common. Even in very recently abandoned milpas little grass is seen except in the extreme northern and western parts of the area visited. Here the many large henequen haciendas, in which the bush has been kept cut for ten to fifteen years, apparently return to bush less rapidly when abandoned and more grass is seen.

The surface outcrop of rock does not seem to interfere much with tree growth. It is not uncommon to see large trees with roots exposed on the rock surface for several meters. Evidently the roots grow out in the thin cover of soil until a crevice is reached, then turn abruptly downward. In rock quarries roots 5 centimeters in diameter have been found 2–3 meters beneath the land surface.

THE MILPA SYSTEM OF AGRICULTURE

Location of milpas.—Difficulty was experienced in learning why a Maya Indian selects a particular site for his milpa. The Mexican Government, in some regions at least, has assigned areas of bush around the several villages for the use of the inhabitants of those villages. If a milpa is made beyond the designated area on Federal land, a tax is exacted by the Government. Milpas have been visited which were 8 to 12 kilometers from the village in which the milperos making them lived. The factors that seem to govern the selection of a site are: type of soil, ease of

cutting the bush, nearness to the village, the presence of water, etc. There are undoubtedly differences in bush soils, though it is not easy to see the difference between what the milpero calls good and poor soils. There appears to be a size range in bush trees on either side of which cutting the trees is more difficult. Trees of more than say 15 centimeters diameter are not easily cut with the small axes of milperos. Likewise, small trees sometimes bend under blows of the axe and must be cut with machetes. Moreover, and perhaps of more importance, in bush made up largely of small trees, there are many more trees per unit area.

When milpas are made near a village, the milperos return to the village after their day's work. When a milpa is more than an hour's walk away—5 or 6 kilometers—the milpero usually moves to his milpa during the periods when he must work more or less steadily. In such instances, nearness to water, a *cenote* or a well, is of prime importance. The necessity of building a fence around a milpa, if near a village, where cattle and horses have free range, may often be a factor influencing the selection of a site far enough away to obviate the necessity for this extra labor.

Making the Milpa.—A site having been selected, the milpero cuts the bush in the early part of the dry season, November to January, and allows the trees to lie as cut until they are dry enough to burn. The largest trees are usually left standing. Among these are the *ramon* tree, the leaves and small branches of which are much used as forage for domestic animals, and the *zapote,* from which the chicle is obtained. The few palm trees, the leaves of which furnish the thatch for Maya huts, are almost never cut. The trees are usually cut at about waist height. Where fences are necessary, many of the smaller trees near the periphery of the milpa are left to be cut as needed for construction of the brush fence. In some milpas, some of the smaller trees are cut at heights of 2 or more meters, the stumps later serving as supports for the bean vines grown with the maize.

In March or April, before the rainy season, the cut and then dry bush is burned. The milpero waits for a day of relatively strong wind and starts his fire on the windward side of the milpa. By this time many of the stumps left standing have sprouts a meter or more long. This new growth is killed by the fire, and if the bush were a heavy one, the stumps and the large uncut trees may be killed, but usually, though considerably burned, many of them are left alive. Lundell, in his "Preliminary sketch of the phytogeography of the Yucatan peninsula," refers repeatedly to devastating fires which not only burn the felled bush but also sweep through the whole countryside. In this visit to northwestern Yucatan, absolutely no evidence of such forest fires was seen. Particular attention was given to this possibility throughout the trip; and in no instance was evidence found of milpa fires having burned for more than a few meters into the surrounding green bush. This study was made before the season of milpa burning, but one large milpa fire near Chichen Itza was watched. Even with a strong wind, the fire burned only the dry leaves and small dead trees for only a few meters beyond the felled bush; and the fire had ceased to burn in the uncut bush while it was still burning hotly

in the trunks of the larger felled trees. Sometimes a milpero takes the precaution of removing the cut bush around the edges of his milpa for a few meters before setting the fire, but most often this precaution is to protect from fire his newly erected brush fence. And perhaps this measure is only apparently one of precaution; the fence is most easily built with the cut bush that is nearest it.

When the rainy season begins, which may be in April or as late as the end of May, the maize is planted. A sharpened stick, usually with a metal point, is used to make a hole in the ground. In this are dropped four or five kernels of maize. Seeds of a native squash and of the common bean (always a black-seeded one) or of a lima bean are mixed with the maize and all are planted together at random. No attempt is made to arrange the hills in rows, and they are spaced irregularly averaging probably a little less than a meter and a half apart. Not infrequently hills are planted in narrow rock crevices or in the deeper pockets in the surface limestone. If this were not done, considerable areas on the low knolls could not be planted at all. Maize seems to grow in rock crevices as well as trees do. In the deeper soils at the base of the range of hills in the western part of the area visited, maize is planted in rows about one and a half meters apart with hills not over half a meter apart in the rows.

Sprouts of tree stumps and weeds that appear in a first-year milpa are cut with a *machete* from once to three times during the growing season of the maize. Very rarely is this done three times and probably more often once than twice. By harvest time the weeds and sprouts have grown to a length of from 1 to 3 meters. When the maize ears begin to mature, the stalks are bent over below the ears, so that the upper part of the stalks, including the ears, hangs down; this is done, it is said, to protect the ears from rain and from birds.

The maize harvest extends over a considerable period of time. It is not uncommon for a milpero to harvest a basket of ears whenever the previously harvested basketful has been used up. By the early part of February, however, most of the maize has been harvested and stored. The ears are gathered into palm-leaf baskets, with the husks on, and piled near a thatched hut in the milpa. The part of the crop that is to be used or sold at once is husked and shelled. Ears that are stored for any considerable period are left in the husks. A crib of stocks is built a little above the dirt floor of the storage hut, and the ears are packed in it tightly in a vertical position with the tips downward. This method of storage is said to lessen injury from rodents and insects.

In preparing a milpa for a second crop of maize, the weeds, stump sprouts, and maize stalks are not cut early in the dry season as was the bush the year before. The cutting is delayed until toward the end of the dry season, it was said because: (1) The small cut stems dry out quickly and therefore need no long drying period; (2) if cut early, more weeds and stump sprouts would grow before burning; and (3) the relatively small amount of trash does not produce a sufficiently hot fire to kill late-grown weeds and sprouts. As a matter of fact, this trash has to be piled as cut in order to insure its burning at all. A serious difficulty arising from this

delayed cutting, seemingly overlooked by the Maya milpero, is that it affords time for the ripening and dispersal of an abundant crop of weed seeds which are not destroyed in any large measure by the fires which burn the piled trash.

The first-year milpa, having been cleared and burned, a second maize crop is planted and tended just as the first one was. For the reason noted above, the weeds on a second-year milpa are much more abundant than on a first-year one. On visiting a milpa it was rarely difficult to decide at once whether it was a first- or a second-year one, using relative abundance of weeds as the sole criterion.

Occasionally, maize is grown on the same milpa for three consecutive years. On the narrow belts of deeper soil at the base of ranges of hills, maize is sometimes grown on the same milpa for four years. But, in an overwhelming percentage of cases, two years is the limit. The milpa is then abandoned to return to bush and a new one prepared by cutting and burning another area of bush. The length of time that a piece of land is left in bush before being cut again for a milpa varies greatly. Rarely, this period is as short as four or five years, and in some instances it is as long as fifteen or twenty years. There is insufficient evidence upon which to base a positive statement of the average length of this bush period, but it is probably not far from ten years. It would seem that the essential factor is a length of time sufficient for the dominant trees to reach a size satisfactory for cutting, and to choke out the smaller bush, and incidentally the annual weeds also.

YIELDS OF MAIZE GROWN BY THE MILPA SYSTEM

As in other places, maize yields in Yucatan vary from season to season. Throughout much of the area visited 1–1½ *cargas* per *mecate* is a good yield for a first-year milpa, and one or a little less than one for a second-year milpa. It should be explained that a *carga* is 42 kilos, or about 93 pounds, approximately 1⅔ bushels, and that a *mecate* is a plot of land 20 × 20 meters, or 400 sq. meters, almost one-tenth of an acre. While yields of 15 to 20 bushels per acre might well be regarded as unsatisfactory to a farmer in the corn belt of the United States, the surprising thing is that so good yields are obtained under the conditions prevailing in Yucatan.

DECLINE IN MAIZE YIELDS

That in general the yield of maize is somewhat less in a second-year than in a first-year milpa is everywhere evident. The bearing of this fact on the customary abandonment of a milpa after the second crop and its possible bearing on the withdrawal from a whole region by the ancient Mayas makes its cause or causes worth more than passing notice.

Soil depletion.—An opinion, apparently somewhat generally held, is that the system of agriculture now practiced by the Mayas results in rapid depletion of soil fertility. Lundell, in his "Phytogeography of Yucatan," says:

> The ashes are the only fertilizer the soil receives, so it is quickly exhausted. Little humus remains after fires have swept the land. The crop is best the first year; the second year it falls off, and in either the third or fourth year the clearing is abandoned and another site is chosen. The abandoned milpas are again placed in cultivation after a lapse of several years, during which interval the fertility of the soil is partly restored by the rank vegetation. Apparently continued rotation leads to complete soil exhaustion . . . .

Since the trees of northern and western Yucatan are hardwoods, and ashes from their burning undoubtedly provide readily available mineral nutrients for the first crop of maize, it seems unlikely that there can be much leaching of these nutrients, for, even after the maize is ripe, the weeds and stump sprouts continue to grow and are not cut until late in spring. It is true also that the fire which burns the dried bush in preparation for the first-year crop burns the few leaves then on the ground and destroys some of the scant layer of humus. Rarely, however, does this destruction of humus extend for more than a couple of centimeters below the soil surface, and that far only where relatively large tree trunks have burned. The burning of stalks, weeds, and stump sprouts preparatory to the second crop has little effect on the remaining humus. This vegetation is so scanty that it has to be piled to insure its burning at all.

One with an agronomic background finds it difficult to believe that milpas, after two crops of maize, have been abandoned because of soil depletion, and equally difficult to conceive of soil fertility, once depleted, being restored by a few years of tree growth. Even without an agricultural background, one might reasonably question how such weeds as amaranths in a second-year milpa could grow to a height of 2–3 meters with a spread of branches nearly equal to their height if the soil were nearing exhaustion.

Weed competition.—In bush of several years standing, such as is felled for a first-year milpa, there are relatively few annual weeds, and these are found mainly along the narrow trails and in the more open parts of the bush. Many of the seeds of these annuals are undoubtedly killed by the intense heat of the burning slash. But some certainly escape, for there is always a considerable number of weeds in a first-year milpa. Since the earlier appearing weeds are cut usually only once, and that during the maize-growing season, weeds continue to grow long after the crop is ripe and are still flowering and only beginning to ripen seed in February; and since these late-growing weeds, along with the maize stalks and stump sprouts, are not cut until near the end of the dry season, there is opportunity for the ripening and dispersal of an abundant crop of seeds. Only a few large weeds may produce enough seed to stock the whole milpa. The burning of scattered piles of trash late in spring can have little destructive effect on the weed seeds which by that time are widely spread over the soil. The system is an ideal one for stocking the second-year milpa with noxious weeds. It seems almost too

obvious to require statement that weed competition rather than soil depletion is the factor primarily responsible for the lessened yield of the second-year milpa. It seems equally clear that tree growth after abandonment of a milpa functions primarily in choking annual weeds rather than in restoring depleted soil fertility.

The labor differential between first-year and second-year milpas.—Statements of milperos agree that more time is required to cut the weeds during summer in a second-year than in a first-year milpa. Moreover, it takes materially more labor to cut, pile, and burn the maize stalks, weeds, and stump sprouts in preparation for a second-year milpa than to cut and burn the bush for a first year milpa. Only from careful records of labor requirements can this differential be accurately determined, but it would not be surprising to find that the preparation and care of a second-year milpa necessitate from one and a half to two times the amount of labor that a first-year milpa requires.

THE MILPA SYSTEM OF AGRICULTURE IN RELATION TO DENSITY OF POPULATION

Dr. Steggerda's study of the dietary of the Maya Indians of the village of Piste indicates that maize furnishes about 85 per cent of the Maya's diet. The problem of food supply adequate for a given population is, therefore, largely one of how much maize can be grown in the region. Dr. Steggerda's records indicate that an average Maya family of five requires annually about 30 cargas of maize. In so far as can be determined from a hurried survey such as this, the usual yield of maize is 1 to somewhat more than 1 carga per mecate, and an average size of milpa for one family is probably not far from 40 mecates. It would seem, therefore, that the Maya now grows enough maize for his family plus what the chickens, dogs, and other animals eat, with some to sell to provide the family with the cheap cotton clothes they wear and the few other purchased articles they require.

Since a milpa is used ordinarily for only two years and then abandoned, and if about a ten-year interval in bush is necessary before the land is again used for maize, a crop can be produced on the average about one year in six. In other words, about 17 per cent of the entire area might be in maize each year. This statement is based on the assumption that none of the land is unsuited to maize production—an assumption that is almost literally true for the parts of the Yucatan peninsula covered in this survey. The water problem could be solved by artificial wells, such as are now in use. What percentage of this area is now in milpas in any one year is not known. But going over the country by rail, automobile, mule cart, and on horse-back, one is impressed by the very small fraction of the country in milpas. This impression was strengthened by observations made in going by air over the entire northern part of Yucatan from Merida to the east coast of the peninsula. While only by accurate records of sample areas can one obtain the necessary information, it would surprise the writer if such records, when obtained, show so much as 1 per cent of the land in milpa at a given time.

If this guess is not too wild to be credited, 15 to 20 times as much maize might be produced each year as is now grown, thus supporting that many times as large a population as is now found in the Yucatan peninsula, and this without changing the present system of milpa agriculture. No evidence was found in this short-time survey to indicate that the present system of milpa agriculture could not be maintained indefinitely. It would seem, therefore, that 15 to 20 times as great a population as the rather sparse one now in existence could find an adequate food supply. Even this figure would probably fall far short of the tremendous density of ancient population postulated by some archeologists in moments of ultra enthusiasm. The factual bases for such estimates are unknown to the writer and are perhaps beyond the powers of comprehension of a mere maize specialist. They do, however, call for a consideration of the possibilities that, in ancient times, a more intensive type of agriculture may have been practiced.

In the territory covered by this survey, there is no evidence of the type of intensive agriculture inferred from mountain-side terraces such as those seen by the writer some years ago near Inca remains in Peru. Of course, no such things are to be expected in a low and flat country such as northern and western Yucatan.

Whether the ancient Mayas employed fertilizers other than the ashes from burned trees or used partly rotted vegetable matter as a manure—as the present-day Maya Indians certainly do not—it is idle to guess.

The advanced civilization of the ancient Mayas would certainly have been capable of inventing tillage implements. They had no beasts of burden, but the postulated population should have furnished man power enough to obviate the need of horses or oxen. Even though the ancient Mayas had no metal tools, they could have made plows and cultivators, as they did axes and knives, from stone and hard wood. But why waste time on such details? Even our modern steel implements of tillage could not possibly be used anywhere in Yucatan except in the deeper soils at the base of the ranges of hills. Even if the outcropping rock did not incapacitate such implements in the first half hour of use, the rocks would keep them from reaching the intervening soil pockets. The main basis for the opinion that ancient Maya agriculture was much like present-day milpa agriculture is the fact that no other type can be regarded as having a chance of successful use. The Mayas of today use the only method available; and the ancient Mayas presumably used the same system for the same reason.

There remains one possibility not yet discussed. Could the ancient Mayas have kept the land in maize more than two years at a time, perhaps many more than two? Or, could they have shortened the interval during which the land was abandoned to go back to bush? By either of these ways the percentage of the whole area in maize at any one time could have been correspondingly increased. The agronomic problem involved in such longer or more frequent use of the land for maize is largely one of greater weed competition resulting in lessened yields or of more labor per unit area to hold the weeds in check.

Information obtained from Maya milperos indicates that it requires from one and one-half to two times as much labor to care for a second-year as for a first-year milpa. Cutting the weeds, stalks, and sprouts in a milpa as soon as the maize is mature enough to harvest, and thus before the weed seeds have ripened and been scattered, instead of waiting as at present until near the end of the dry season, should materially lessen the weeds to be fought the next season. But there is no way of knowing whether the ancient Maya's routine differed from that in vogue at present.

How much time does a Maya spend in caring for a milpa large enough to supply his dependents with maize for the year? If the ancient Mayas used materially more than one-sixth of the land for maize each year, could the milperos have devoted enough time to their milpas to meet the weed problem involved? A milpero cuts about two mecates of high bush a day. In cutting the trash in preparation for a second-year milpa, he covers about the same amount of land, but this takes the greater part of a day, while cutting two mecates of bush for a first-year milpa seldom requires all day. Two mecates seem to be the day's stint, irrespective of how many hours of work are required. Rarely is more than one mecate cleaned of weeds in one day's work during the growing season of maize in a second-year milpa. Under the present system, therefore, to prepare land enough for the maize needed by one family—say 40 mecates, or about 4 acres—and to weed it once in summer requires about sixty days of labor for one man. Burning the felled trees or the weeds and stalks, planting, and harvesting could hardly require more than twenty days. It follows that the present-day Maya milpero has about three-fourths of his time free from the labor necessarily connected with his milpa. The ancient Maya milpera grew cotton as well as maize, but the Maya of today grows enough more corn so that he can sell some in order to buy cotton cloth. Moreover, the ancient milperos must have grown enough maize for their priests and rulers in addition to the requirements of their own families. But even so, the ancients could have spent more time on their milpas than do their descendants of the present time, and still have had much time in which to build pyramids, temples, and the like. All this, if true, suggests that the present milpa system of agriculture, with only minor modifications, could have supported a very much greater population than is found today in the Yucatan peninsula—how much greater only careful long continued studies can determine.

What effects longer and more frequent use of the land for maize growing would have on soil fertility is beyond the writer's ability at guessing. Certainly soil erosion could have played no part in bringing about the abandonment of a low, flat region like that around Chichen Itza. There is no evidence whatever, so far as one who is not a geologist can determine, to indicate the presence of such "washes" as one sees commonly in the much drier regions, deserts, of California. But these regions are bordered by real mountains, not merely the low hills of Yucatan; and the steepness of their slopes is a surprise to any automobile driver who is likely to have his engine stall on what seems almost level ground.

The absence of erosion in northern and western Yucatan is no argument against the possibility that erosion was an important factor in causing the abandonment of the higher and more broken regions farther south where the old-empire Mayas flourished for a time only to abandon the area later and migrate to the low lands of Yucatan. Whether or not the erosion theory is the correct answer to the abandonment of the territory of the old-empire Mayas, it is now serving a useful purpose as the goblin of the present erosion campaign in the United States.

RECOMMENDATIONS

The survey here reported was only a preliminary study. Although statements of milperos are perhaps correct, many of the figures given here are at best only estimates and some of them are guesses, perhaps very poor guesses. At best a hurried survey could not be expected to do more than to indicate what the elements of the problem are and to suggest the kinds of accurate information needed.

The writer is convinced that weed competition and the labor involved in weed control is a more important factor than soil exhaustion, and yet, the latter might enter to a greater or less degree, particularly if the land were used for maize culture for relatively long periods and at relatively frequent intervals. The only way to get reliable information concerning the possible depletion of soil fertility by maize culture is to conduct, for several years, a carefully planned and carefully executed field-plot experiment. But this would require the services of a man trained in modern agronomic technique for at least part of each year, and of a trustworthy helper to keep detailed records during the growing season.

But there are problems of perhaps more immediate importance which should be undertaken at once, if their solution is of enough importance archeologically to warrant the expense involved. And, for the solution of these problems also, it is of prime importance to have a well-trained man with a well-founded agronomic background. Such a study should provide accurate information to take the place of the hear-say evidence, the estimates, and the guesses presented in this report.

It would seem sufficient to select six or eight sample areas, such as the territory contributory to Piste already studied in part by Dr. Steggerda. It is important to know the number of people gaining their support in a given area, the amount of maize produced and used for food by them and their domestic animals, or sold in order that other necessities may be purchased, the number of mecates cultivated in order to provide this maize, and the relation that the area of all the milpas bears to the entire area. Accurate information should be obtained also respecting the hours of labor per unit area devoted to each separate operation involved and in the preparation and care of milpas.

If a field-plot experiment is undertaken, one series of plots should be kept free from weeds at whatever cost, while another series is cared for as the Mayas now tend their milpas. Such an experiment should afford information not only in respect to possible soil depletion, as measured by maize yields, but the labor records should be of value in appraising the possibility that the ancient Mayas may have kept the land in milpas a greater percentage of the time than is now done.

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